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FAMOUS AMERICAN MEN OF SCIENCE

BY J. G. CROWTHER

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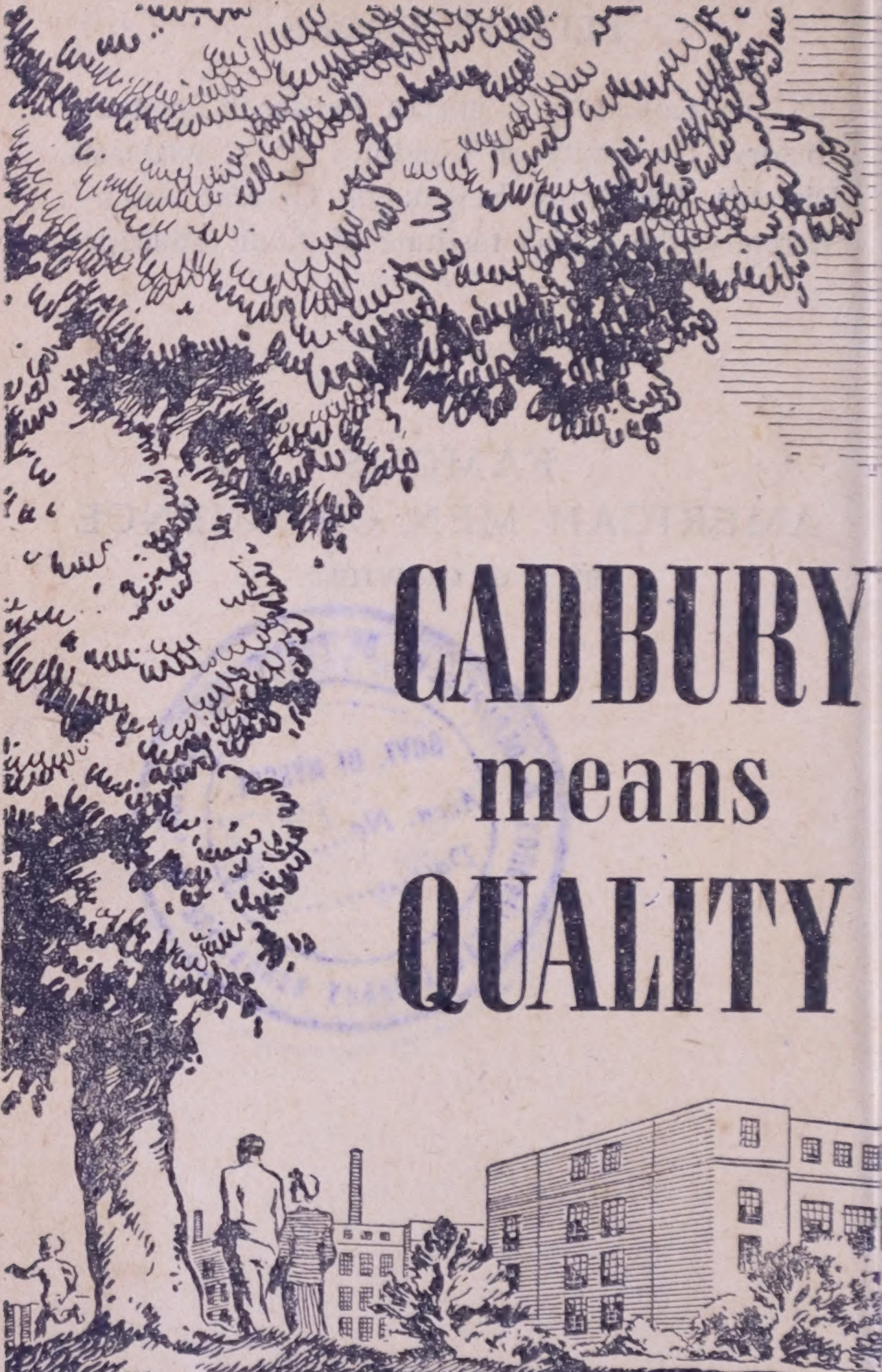
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PELICAN BOOKS

FAMOUS AMERICAN MEN OF SCIENCE

BENJAMIN FRANKLIN
JOSEPH HENRY

BY

J. G. CROWTHER

Volume I

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PUBLISHED BY
PENGUIN BOOKS
HARMONDSWORTH MIDDLESEX ENGLAND
245 FIFTH AVENUE NEW YORK U.S.A.

First Edition 1937
Published in Pelican Books, 1944

MADE AND PRINTED IN GREAT BRITAIN FOR PENGUIN BOOKS LIMITED
BY R. & R. CLARK, LIMITED, EDINBURGH

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FOREWORD

THE present age is often described as scientific. Science and technology have a very important part in modern life. Many persons believe that the economic and social disasters of today are due to the development of science. Owing to the application of science, almost any sort of goods can be made in almost any country in almost any amount. The old balance of industry within countries, and between countries, has been upset. If the world economic depression is due even in part to the growth of science and technology, then science and technology are clearly of enormous social, besides productive, importance in modern life. The investigation of the rôle of science in modern life becomes a social duty.

This book on American Men of Science is a contribution towards this investigation. It contains an account of the scientific work and lives of Benjamin Franklin, Joseph Henry, Thomas Alva Edison, and Josiah Willard Gibbs. The relations between the problems they chose to work upon, and the social needs of their times, are pointed out. Explanations are offered of the reasons why Franklin created the modern theory of frictional electricity, and Henry invented the large electromagnet and developed the Smithsonian Institution, why Edison invented the quadruplex telegraph, modern electrical engineering, and the gramophone, and why Gibbs studied the theory of heat and created the theoretical basis of physical chemistry.

All of these things were done in America. Have they any relation to the characteristics of American life?

The progress of science is not accidental. It is due to the needs of the society in which it occurs, and its direction is affected by the conditions of that society.

It is shown that Franklin's electrical researches were conditioned by two climatic factors. He moved from Boston to Philadelphia. As Bogart has remarked, the cold climate of Boston encouraged the wearing of woollen clothes, whereas linen was more commonly worn in Philadelphia. As a consequence, Philadelphia became a depot for linen rags, and hence the centre for the raw material of the paper trade. Franklin made a fortune out of paper and printing, and thereby secured the means to buy scientific apparatus, and the leisure to use it. The dry winter climate of the American

Atlantic coast made the insulation of electricity easier. Frictional electric machines worked more satisfactorily, and gave more clear-cut results. The definiteness of the results helped Franklin to obtain a clearer conception of the behaviour of electricity.

Franklin's greatest gift was the modernity of his mind. He had the most advanced mind of the eighteenth century. He inspired Joseph Priestley to start research, and, as is not generally known, was a necessary part of the chain of causes which enabled James Watt's steam-engine to be introduced in industry. He also had an important influence in the creation of chemical industry. He had a marvellous power of perceiving the significance of men. He manipulated and experimented with men as others with things.

The next outstanding figure in American science was Joseph Henry. He was the inventor of the first practicable electro-magnet and electric telegraph. He probably discovered electro-magnetic induction before Faraday, though he was five years younger, and had far less opportunity for research. He unconsciously made experiments with radio waves in 1842. The latter half of his life was spent in the creation of the Smithsonian Institution. In religion and science Henry had very orthodox views. He believed that scientific discovery was a pure activity without any necessary connection with industry and social affairs. And yet, during the second half of his life, his researches were concerned exclusively with problems of economic interest to agriculture and navigation, such as meteorology and fog-signal acoustics.

The Smithsonian Institution was conceived by James Smithson through a desire for social revenge. He was the illegitimate son of the first Duke of Northumberland, and his mother was of royal descent. He resented being disowned by his father, and left his money to the United States in order to found an institution which would be famous when the names of English noblemen had been forgotten. The spectacle of the gentle and pious Joseph Henry conscientiously realizing Smithson's wishes by the creation of the famous Institution is one of the most remarkable in the history of science. It raises many questions concerning the relations between Puritan philosophy and the rise of science, and the influence of class feelings on the motives of individuals.

The Smithsonian Institution is a monument to the Oedipus complex.

The third subject is Thomas Alva Edison. The question whether the title "scientist" should be applied to him is discussed. It is concluded that the separation of pure science, applied science, and invention, prevents a true understanding of the history of science. Faraday, Henry, and Maxwell would have had little influence on the world without Bell, Edison, and Marconi. The study of Edison makes the influence of Faraday's discoveries much clearer. The relation of Edison's personality and psychology to the social types and classes which achieved dominance after the Civil War is analysed. The connection between his inventions and the social and industrial development of the country is explained, and it is seen that his life's work provides some of the most illuminating evidence known in history of the rôle of science in human society. His contribution towards the reduction of invention to a rational and businesslike activity is considered to be his greatest contribution to civilization. He attempted to remove the ancient elements of magic and mystery from invention, and to incorporate it as part of a rational social system.

The figure of Josiah Willard Gibbs is equally extraordinary. He died within a few hundred yards of where he was born. He became professor of mathematical physics in Yale College, where his father had previously been a professor of Hebrew and sacred literature. In a short period of five years he published a masterpiece of research which has proved to be the foundation of several new branches of science. One of the results of this work showed how mixtures of chemicals could be handled successfully on an industrial scale. In the 1914–18 War, England was in danger of destruction through lack of explosives, until one of her chemists showed how to manufacture the needed quantities of ammonium nitrate by the application of Gibbs' phase rule.

During his lifetime Gibbs' genius was little recognized in America, and not sufficiently recognized in Europe. The explanations of this phenomenon, in terms of the social and intellectual atmosphere of the United States, are dealt with.

In the course of the discussions, general aspects of the relation of science to social organization are considered; in particular, the influence of scientific ideas in framing the American Constitution. As Woodrow Wilson pointed out, the men who made the Constitution adopted the notion of balances of power between the President, Congress, and the Supreme Court, from Newtonian mechanics. Thus Newtonian mechanics have helped to produce the present deadlocks in American Constitutional affairs. As is well known, Benjamin Franklin was opposed to the Constitution. He agreed to it only because the Convention would not accept a better. It is argued that he opposed the Constitution because he had the spirit of a modern experimental physicist, and, unlike his lawyer colleagues, was not overawed by the prestige of Newtonian ideas.

In concluding this foreword, I have pleasure in recording a number of indebtednesses and kindnesses.

B. Hessen's essay on *The Social & Economic Roots of the Ideas of Isaac Newton* first showed me how science might be interpreted as a product of human history, in contradistinction to the traditional view that science exists as a thing in itself, with no necessary connection with other things.

Mr. James B. Conant, the President of Harvard University, invited me to lecture at Harvard on the History of American Science. I am deeply grateful for this honour. My lectures are based on the substance of this book.

The authors mentioned in the bibliographies given at the ends of the sections have provided essential information. I am particularly indebted to the work of Messrs. Dyer, Martin, and Meadowcroft on Edison.

Dr. J. A. V. Butler has read the chapter on Willard Gibbs, and has helped to remove some of the obscurities from it.

The Yale University Press kindly presented me with proofs of the *Commentary on the Scientific Writings of J. Willard Gibbs*, so that it was not necessary to wait for publication before having the advantage of examining this work.

Mr. H. M. Cashmore, the City Librarian of Birmingham, England, gave valuable information on Dr. William Small.

I am glad also to thank my publisher and his staff for the extra labour they have given in the passage of the book through the press.

J. G. CROWTHER

March, 1937

GENERAL BIBLIOGRAPHY

FOR VOLS. I AND II

The Rise of American Civilization. Charles A. Beard and Mary R. Beard. 2 volumes. 1927.

The Education of Henry Adams. Henry Brooks Adams. 1918.

Economic History of the American People. Ernest Ludlow Bogart. 1930.

The Federalist. Hamilton, Madison, and Jay. EVERYMAN EDITION.

The Theory of the Leisure Class. Thorstein Veblen. 1899.

Constitutional Government in the United States. T. Woodrow Wilson. 1908.

Civilization and the Growth of Law. W. A. Robson. 1935.

The Declaration of Independence. Carl Becker. 1933.

Freedom versus Organization: 1814–1914. B. Russell. 1934.

Works of Alexander Hamilton. Edited by H. C. Lodge. 1885.

The Spirit of Laws. Montesquieu, with D'Alembert's analysis.

John Adams: Works. Edited by C. F. Adams. 10 volumes. 1850–1856. Including a *Life* (Volume I) by C. F. Adams, and the *Defence of the Constitutions of the United States of America* (Volume IV).

An Economic Interpretation of the Constitution of the United States. Charles A. Beard. 1925.

The Writings of Thomas Jefferson. Collected and edited by Paul Leicester Ford. 10 volumes. 1899.

Lincoln. W. E. Barton. 2 volumes. 1925.

Lincoln: The Prairie Years. Carl Sandburg. 2 volumes. 1926.

My Diary North and South. W. H. Russell. 2 volumes. 1863.

The History of the American People. Charles A. Beard and William C. Bagley. 1923.

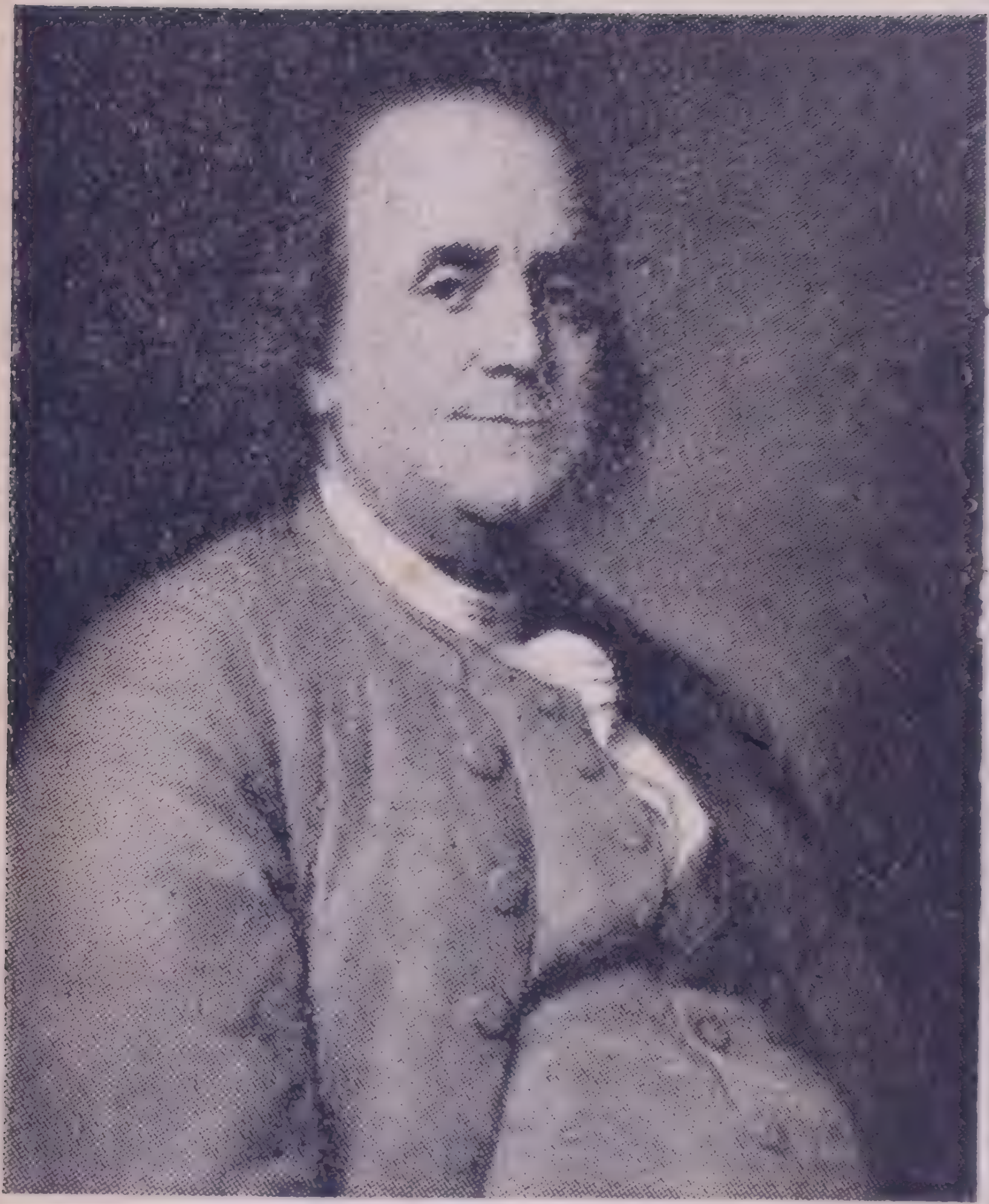
The American Presidents. Herbert Agar. 1933.

The Life Story of J. Pierpont Morgan. Carl Hovey. 1912.

Prosperity: Myth and Reality in American Economic Life. M. J. Bonn. 1931.

BENJAMIN FRANKLIN

1706–1790



BENJAMIN FRANKLIN

(*Portrait by Duplessis*)

I

THE SCOPE OF HIS IDEAS

1

THE lives of few very great men are as accessible as Franklin's, or have been as thoroughly studied. The completest familiarity with the features and details of his life has not dulled their wonders.

The early date of his birth is continually arresting. He was born only ninety years after Shakespeare died. The comprehensive fertility of his imagination shows his kinship with the great spirits of the Renaissance. He had their love of personal freedom, and was not a puritan, as he was complacent of the illegitimacy of his son, grandson, and great-grandson. The edge of his defence of Polly Baker proves his freedom from sexual complexes and the repressive conventions of the classes which afterwards dominated the nineteenth century. The young friend of Mandeville was never transformed into a courtier of Mrs. Grundy.

Franklin's unsurpassed discretion in diplomacy proves his unconventional behaviour was not due to lack of self-control. His *Autobiography* is a description of one of the most extraordinary examples of the conscious organization of a life. To what sort of material was this organization applied? Exceptional physical and mental vitality, and strong passions. He was a powerful swimmer, and thought of becoming a teacher of swimming in London. He lived eighty-four years, during which his activity was almost unparalleled. He published writings during sixty-eight years. It is difficult to recall any other man who wrote sensibly for such a period. Few men of high talent write sensibly for more than thirty years. His vitality enabled him to live actively for double the normal period. He seemed to have had two lives. His first life, when he was influencing the affairs of Boston through journalism at the age of sixteen, was not quite beyond the echoes of Shakespeare's time; and the voice of his second life, when he was participating in the formation of the American Constitution at the age of eighty-one, carried clearly into contemporary times. He was sufficiently far from the

Elizabethans to avoid their indiscipline, and he matured before the puritan capitalists had established the dominance of their conventions. He shed the mark of any particular period, and became, like Shakespeare, partly a member of all generations. This is one explanation of his modernity.

Faÿ has given an illuminating description of the social life in Boston during Franklin's youth. There was a dominating group of rich merchants and a turbulent class including colonial seamen and adventurers. Franklin's brother conducted a radical newspaper which reflected the free spirit of the latter class. Franklin received the first opportunity for expressing his personality through this newspaper. He swiftly discovered that radicalism had no future in Boston, so he escaped to Philadelphia, which was less under the shadow of the nineteenth century. These circumstances saved him from being blighted with the cultural narrowness of the industrialism which grew rapidly after the middle period of his life. Franklin's cultural superiority over his successors is demonstrated by the superiority of his style. He could modulate his instrument to the expression of almost all human interests. He was not driven by spiritual anxiety to use a machine-gun style.

The poise of his style and diplomacy was acquired through exercise of his passions and faculties. His temperament was of the sanguine type, which, according to Pavlov, is the best. He cultivated this fortunate temperament, which was in contrast to that of the diplomatically inept Adams, whose mind was tied up with New England complexes. The famous phrase "*Ça ira*" is an expression of the sanguine temperament.

His praise of economy and practice of self-discipline are additional evidence of his vitality. They were reactions from the natural extravagance, loose-living, and disorderliness, which he criticizes in himself. The outspoken letters he wrote to women in his youth, and his cultivated and amiable relations with women in later life, prove that his sexual passions had been properly moulded. He proposed to Mme. Helvetius when he was about seventy-five years old, and rationalized his sexual interests by trying to arrange the marriage of his son to Polly Stevenson, his grandson to Mlle. Brillon, and his nephew to Mlle. Schweighauser. All of these attempts were unsuccessful, so he probably had more interest than his young relatives in them. A modern psychologist could not have given him better psychological health than he achieved.

He created his literary style mainly out of Addison's, though he was influenced by Bunyan and Defoe. Addison was one of the chief inventors of the mode of literary expression used by the educated part of the English merchant class, who had recently gained control of England. It was the style of a new governing and leisure class whose power was founded on trade.

Franklin adapted the style of the intellectuals of the new English leisure class of 1710–1720 to the purpose of another social class or classes, the small men of property and craftsmen, the American democratic radicals, whom he had joined in Boston, and whom he never completely deserted, for he protested in their interests against the adoption of the American Constitution. He succeeded because he was an American, as these classes were far more powerful at that time in America than in England. His literary virility and greatness was partly due to his creation of a cultural hybrid between the intellectual modes of expression of two social classes. The superior technique of the English leisure-class style was put to the service of the rising American small men of property. English writers pursuing the same object, such as Defoe, had less immediate success, because the prestige of the merchant-capitalist class was at that time greater in England than in America.

Franklin wrote that Pennsylvania adopted his proposal to issue paper money because he was a better and more convincing writer than any that could be hired by the rich to oppose it.

He lost reputation during the nineteenth century partly because the capitalist and financial classes, which he had opposed, attained almost complete control of American life. His reputation is rising again in the twentieth century, as the opposition to those classes strengthens.

He was mainly a representative of the small man of property. This is the basis of the view of writers such as Faÿ, who describe him as the first bourgeois to attain full human dignity. He was the first bourgeois to stand before kings, without discarding the social and philosophical attitudes of his class, and acquiring those of aristocracy.

This was a great contribution to social emancipation. But Franklin was not only a bourgeois, a small man of property. He was also a representative of craftsmen, and an experimental scientist. In his epitaph he describes himself as a printer, not as a man of property. As the representative of craftsmen and scientists he spoke for the rising classes of the future, the modern men.

The essence of the bourgeois, or small man of property, and the worker or craftsman, has been depicted in Daumier's famous cartoon. Franklin could have spoken for both of those figures, though probably more for the bourgeois. In his later years he was no longer a small man of property, but his strong intelligence prevented him from automatically acquiring the philosophies of the rich. His speeches in the Constitutional Convention did not represent the views of any single class, and least those of the rich. Franklin is bourgeois according to the intellectual characteristics of that class, as described in the brilliant writings of Thorstein Veblen. The habits of thought of the leisure or governing class "run on the personal relation of dominance, and on the derivative, invidious concepts of honour, worth, merit, character, and the like. The causal sequence which makes up the subject matter of science is not visible from this point of view. Neither does good repute attach to knowledge of facts that are vulgarly useful." Members of the leisure class with sufficient mental ability to investigate the external world are commonly "diverted to fields of speculation or investigation which are reputable and futile." "Such indeed has been the history of priestly and leisure class learning." "But since the relation of mastery and subservience is ceasing to be the dominant and formative factor in the community's life process, other features of the life process and other points of view are forcing themselves upon the scholars."

Franklin's intellectual attitude is the perfect illustration of what is to be expected in leisure-class scientists "of lower-class or middle-class antecedents—that is to say, those who have inherited the complement of aptitudes proper to the industrious classes, and who owe their place in the leisure class to the possession of qualities which count for more to-day than they did in times when the leisure class scheme of life took shape."

Veblen explains that the growth of science is intimately related to the concentration of the human intelligence on industrial processes. The attention to the properties of materials and the effects of treatment, develops the notion of cause and effect. The spread of this notion undermines the concepts of animism, divine right, and innate superiority in the upper classes. The various branches of science have "made headway . . . in proportion as each of them has successively escaped from the dominance of the conceptions of personal relation or status, and of the derivative canons of anthropomorphic fitness and honorific worth." Scholasticism and classicism were by-products " of the priestly office and the life of leisure, so modern science may be said to be a by-product of the industrial process."

While Franklin was intruding into science, on behalf of the lower middle class, concepts which appeared vulgar to the intellectuals of a former leisure class, John Adams was intruding equally vulgar upper middle-class ideas into law. He remarks that the ancient nations uniformly believed " the Divinity alone was adequate to the important office of giving laws to men . . . and modern nations, in the consecration of kings, and in several superstitious chimeras of divine right in princes and nobles, are nearly unanimous in preserving remnants of it. Even the venerable magistrates of Amersfort devoutly believed themselves God's viceregents . . . is it that obedience to the laws can be obtained from mankind in no other manner . . . are . . . no considerations of public or private utility . . . sufficient to engage their submission to rules for their own happiness ? "

Adams wished to substitute the philosophic rationalism, that had been developed by commerce and industry, for the notions of divinity or dominance, as the authority which should convince or persuade men to accept the laws.

2

The character of Franklin's career was influenced by the American climate in at least two ways. Franklin acquired wealth from the printing and paper trade that developed in Philadelphia. He was carried into a position from which he could achieve fame by the growth of these trades, which was due in a considerable degree to local climatic and social conditions. E. L. Bogart has explained that the populations in Philadelphia and Boston wore linen and wool respectively, because the climate of the one was warm, and of the other relatively cold.

Owing to these habits, linen rags were more plentiful in Philadelphia than in Boston. As at the time paper was made out of linen rags, Philadelphia had an advantage as a centre for paper-manufacturing, and the industry naturally grew there.

Philadelphia had attracted many Dutch and German settlers. In the eighteenth century the Dutch had exceptional skill in paper-making. One of their countrymen, Rittenhouse, introduced the manufacture in 1690. Thus the Philadelphia paper trade started with the combined advantages of climate and skill. Franklin and his friends were helped in their scientific experiments by the high standard of manual and technological skill largely due to the Dutch and German settlers. He writes that Philadelphia mechanics could make very good instruments. He had no difficulty in having apparatus made to his designs. One of Franklin's best friends was a Rittenhouse, who was a capable observational astronomer. Franklin gained part of his fortune from investments in eighteen paper mills consuming linen rags. He refers to the energetic assistance he received from his wife in the collection of linen rags.

Today most paper is made out of wood-pulp and esparto grass. The linen trade in England had declined so much by 1937 that it is no longer possible to collect enough fine linen rags in England for the manufacture of the paper for the Bank of England's famous five and ten pound notes, known as "fivers" and "tenners." The paper for these is made from fine linen rags imported from France, as the linen of English rags is now too coarse for the purpose.

This phenomenon reflects considerable changes in English social life. It shows that fine linen is rarely worn; that the taste of the English middle classes in underclothes is declining (parallel to the decline of its taste in literature, the theatre and other branches of culture), and that linen is being replaced by artificial silk. It is also a reflection of the greater warmth of the French climate, which preserves the wearing of linen in France.

If paper had been made from wood and clothes from artificial silk in the eighteenth century, Philadelphia would not have become the centre of the paper and printing trades, journalism and libraries, and Franklin would not have been carried to power by their growth. He might not have succeeded in making a fortune and retiring at the age of forty in any other trade, or in any other town, and without leisure he would not have become a world-famous scientist. Without his scientific fame he would not have become America's diplomatic genius at Paris. If there had been no linen rags in Philadelphia, there might have been no famous Franklin, and American independence might have been delayed fifty years.

Franklin was helped to economic independence by the Philadelphia climate. He received equally important help from the climate in his electrical researches. When the wind at Philadelphia blows from the north-west, it comes from the interior of the North American continent, and is often extremely dry. Franklin frequently commented on the dryness of the north-west winds. The dryness, which was increased in winter by severe frost, very much facilitated experiments in electrostatics, owing to the dependence of the electrical insulating properties of materials on freedom from moisture.

It is very much easier to draw sparks by combing the hair in a dry North American winter than in a moist English winter, as many persons know from experience. It is even possible to light the gas by drawing sparks from the fingers. Electrostatic experiments made with materials such as glass and fibres, which attract moisture, are much more difficult in damp climates such as those of England and Western Europe, than in North America. English schoolboys are only too familiar with the physics textbooks' account of experiments in electrostatics, with rods of glass and pieces of wool and silk, which do not work satisfactorily. Owing to the moist climate, elementary experiments in electrostatics are as difficult and confusing to the English student as introductory lectures on the theory of limits in the differential calculus.

Until recently, English students were introduced to the study of electricity by experiments in electrostatics. Generations of them have suffered discouragement by this practice, as electrostatical experiments are not easy or convincing when attempted by inexperienced experimenters in a moist climate. The growth of the general knowledge of electrical science in England has been retarded by this mistake in the method of teaching.

Franklin and his friends could make good apparatus in Philadelphia, owing to the excellence of the craftsmen, and the good insulation provided by the dry climate helped them to get strong sparks and striking effects. The striking, easily repeated experiments assisted them to think out clear-cut theories. Nature put her electrostatical problems more clearly to Franklin than to Western Europeans. This helps to explain why Franklin advanced the theoretical analysis of electrostatical phenomena beyond the stage reached in Europe.

The American climate may have had some effect on Franklin in another way. Concerning Hamilton's style, H. C.

Lodge has written : " There is nothing vague or misty about Hamilton. Everything is as clear and well-defined as the American landscape on a bright, frosty autumn day." Franklin may also have been inspired by the clarity of the American landscape on such days (which happen to be particularly good for experiments in electrostatics).

If the qualities of the climate are able directly to mould those of the mind, evidence of this might be expected in Franklin, who was interested in the weather, and naturally observant. He deduced the track of the cyclonic storms from the observation that an eclipse of the moon was visible at Boston, though obscured by a storm at Philadelphia. This proved the storm visited Philadelphia first, though the wind blew from the northeast. He estimated that the whole storm moved at about one hundred miles per hour. He gave a remarkable theory of how they probably arose in the Gulf of Mexico, and considered them similar in nature, though vastly greater in scale, to water-spouts and whirlwinds.

Franklin's experiments on the absorption of solar radiation by coloured bodies are a beautiful example of his scientific ability and utilization of qualities of the American climate. They depend on an adroit exploitation of the snow and hot sunshine available in a North American winter, but not in an English winter. In one of his pedagogic letters to Miss Mary Stevenson, written in 1761, he explains to her that rivers may not run into the sea, as their water may evaporate before it reaches the river mouth. When a river disappears before reaching the sea " the Ignorant might suppose, as they actually do in such cases, that the River loses itself by running under ground, whereas in truth it has run up into the Air." He discusses the evaporation of water by the sun's rays, and describes experiments on the absorption of heat by bodies of different colours.

" But first let me mention an Experiment you may easily make yourself. Walk but a quarter of an Hour in your Garden when the Sun shines, with a part of your Dress white, and a Part black ; then apply your hand to them alternately, and you will find a very great difference in their Warmth. The Black will be quite hot to the Touch, the White still cool. Another. Try to fire Paper with a burning Glass. If it is white, you will not easily burn it. But if you bring the Focus to a black Spot, or upon Letters, written or printed, the Paper will immediately be on fire under the Letters.

" Thus Fullers and Dyers find black Cloths, of equal

Thickness with white ones, and hung out equally wet, dry in the Sun much sooner than the white, being more readily heated by the Sun's Rays. It is the same before a Fire; the Heat of which sooner penetrates black stockings than white ones, and so is apt sooner to burn a Man's Shins. Also Beer much sooner warms in a black Mug set before the Fire, than in a white one, or in a bright Silver Tankard.

"My Experiment was this. I took a number of little square Pieces of Broad Cloth from a Taylor's Pattern-Card, of various Colours. There were Black, deep Blue, lighter Blue, Green, Purple, Red, Yellow, White, and other Colours, or Shades of Colours. I laid them all out upon the Snow in a bright Sunshiny Morning. In a few hours (I cannot now be exact as to the Time), the Black, being warm'd most by the Sun, was sunk so low as to be below the Stroke of the Sun's Rays; the dark Blue almost as low, the lighter Blue not quite so much as the dark, the other Colours less as they were lighter; and the quite White remain'd on the Surface of the Snow, not having entered it at all.

"What signifies Philosophy that does not apply to some Use? May we not learn from hence, that black Clothes are not so fit to wear in a hot Sunny Climate or Season, as white ones; because in such Cloaths the body is more heated by the Sun when we walk abroad, and are at the same time heated by the Exercise, which double Heat is apt to bring on putrid dangerous Fevers? That Soldiers and Seamen, who must march and labour in the Sun, should in the East or West Indies have an Uniform of white? That Summer Hats, for Men or Women, should be white, as repelling that Heat which gives Headaches to many, and to some the fatal Stroke that the French call the *Coup de Soleil*? That the Ladies' Summer Hats, however, should be lined with Black, as not reverberating on their Faces those Rays which are reflected upwards from the Earth or Water? That the putting a white Cap of Paper or Linnen *within* the Crown of a black Hat, as some do, will not keep out the Heat, tho' it would if placed *without*? That Fruit-Walls being black'd may receive so much Heat from the Sun in the Daytime, as to continue warm in some degree thro' the Night, and thereby preserve the Fruit from Frosts, or forward its Growth?—with sundry other particulars of less or greater Importance that will occur from time to time to attentive Minds?"

Franklin's contribution to the study of the absorbent properties of common materials has even today not been completed. The Army authorities in England have been inspecting with much enthusiasm recent experiments on the absorbent properties of clothing and building materials, suitable for uniforms and barracks in tropical countries.

Extensive experiments have been made in America to determine the best colours and compositions for the paints used to cover the tanks for storing petroleum. The evaporation of the oil in tanks is wasteful and dangerous, so it is desirable that as little as possible of the heat in the sun's rays should pass through the walls of the tanks into the oil. Experiments have proved that paints such as aluminium paint are the most effective, and minimize evaporation.

3

The clarity of Franklin's thought owed probably more to social than to climatic influences.

The American provinces were still young pioneer communities in Franklin's time. A powerful class of academic scientists had not yet grown. As late as 1801 Priestley, who was then in America, wrote to Humphry Davy that he was " perfectly insulated " from scientific news and developments, owing to the small and scattered number of scientists in the country. Such conditions have bad and good effects. They prevent many men of ability from discovering their bent through education. But if a man has a mind powerful enough not to have to lean much on academic science, such conditions may protect him from acquiring false traditional ideas. Franklin's mind was of this powerful order, and he benefited by his freedom from preconceived notions acquired in European academies. The isolation which would have killed the scientific work of a lesser man protected him from misleading intellectual fashions. The European academic tradition was non-scientific. The study of science at Oxford and Cambridge was not in a healthy condition. The experimental science of the succeeding centuries was being founded outside universities by self-taught investigators such as Guericke and Priestley, and later, Davy and Faraday.

As J. D. Bernal has remarked, Priestley's researches were largely inspired by Franklin. Indeed, Priestley says so. Priestley had a very powerful mind but it was not so bold or keen as Franklin's. Davy wrote of Franklin with profound respect, and deeply appreciated his combination of expository and investigatory power.

4

The masterfulness of Franklin's mind has not been sufficiently recognized. He controlled the intellectual destinies of many remarkable men. Besides deciding the direction of Priestley's career, he influenced that of William Small.

This Scottish mathematical and medical doctor was born in 1734. He emigrated to America and became professor of natural philosophy in Williamsburg. Thomas Jefferson attended his lectures. Jefferson writes in his autobiography that Small " probably fixed the destinies of my life." Jefferson's confidence in the value of rational inquiry, and his distrust of legalistic political forms, may have been strengthened by Small's instruction in science. American political ideas show many peculiar marks of scientific influences. Small and Jefferson were two of the most important agents through which science has left these marks on American political thought. Small's influence on history did not end by fixing the destinies of Jefferson's life. He appeared in another event of immense historical importance. With Matthew Boulton of Birmingham, England, he assisted James Watt to draw up the patent specification of his steam engine with a separate condenser. This was the most important patent in history, and the largest single contribution to the development of modern industrialism.

According to an article by J. Hill, published in the *Birmingham Weekly Post* in 1899, Small's settlement at Birmingham was due to Franklin. Hill writes that Franklin probably became acquainted with Small at Williamsburg.

Franklin made his third visit to England in 1764, and Small returned from America about the same time. Franklin had become acquainted in 1758 with Boulton, the great Birmingham magnate by whom the modern principles of standardization, mass-production and factory organization, were chiefly founded. In May 1765 Franklin gave Small a very earnest written introduction to Boulton. This letter enabled Small to secure Boulton's friendship, and a practice as a medical doctor in Birmingham. Small was a close friend of another Scot, James Watt.

Boulton's engineering factory at Soho, Birmingham, employed six hundred skilled workmen, at that time a huge number. The machinery was driven by a water-wheel. In dry summers there was not enough water to drive the water-wheel. Boulton conceived the notion of installing a steam pumping-engine that would pump the water, after it had run through the water-wheel, back to the supply channel, so that the same water could be used over and over again for providing the factory with power. This arrangement would have made the power supply independent of the weather. L. T. Hogben has informed the writer that other manufacturers in the adjacent pottery district had the same idea, and Boulton may have got it from them.

Such was the scheme which gave Boulton an interest in steam engines. Small saw that his Glasgow friend Watt, with his improved steam engine, might be able to meet Boulton's demand for more satisfactory sources of power for driving his factory. Small strongly urged Watt to come to Birmingham and settle in the town. Watt first visited the Soho factory in 1767, and in Boulton's absence, was shown over it by Small.

For six years Small worked incessantly to promote a partnership between Boulton and Watt. He succeeded in 1774, and Watt settled in Birmingham.

In the next year, 1775, when Small was also about to join the partnership, he died. This is probably the reason why he is not more famous. No publication by him appears in the catalogue of the library of the British Museum.

Boulton and Erasmus Darwin, the grandfather of Charles Darwin, were present at his death. Darwin wrote to a friend on February 25th, 1775 : " I am at this moment return'd from a most melancholy scene, the death of a Friend who was most dear to me Dr. Small of Birmingham, whose strength of reasoning, Quickness of Invention, Learning in the discoveries of other men and integrity of Heart (which is worth them all) had no equal. Mr. Boulton suffers an inconceivable Loss from the Doctor's mechanical as well as medical abilities."

Boulton erected a monument to Small in the grounds of his factory. It was inscribed with the following epitaph, composed by Darwin at Boulton's request :

Ye gay and young, who thoughtless of your doom
   Shun the disgustful mansions of the dead,
Where melancholy broods o'er many a tomb,
   Mouldering beneath the yew's unwholesome shade.

If chance ye enter these sequester'd groves,
   And day's bright sunshine for a while forego,
Oh, leave to Folly's cheek the laughs and loves,
   And give one hour to philosophic woe !

Here, while no titled dust, no sainted bone,
No lover weeping over beauty's bier,
No warrior frowning in historic stone,
Extorts your praises, or requests your tear.

Cold Contemplation leans her aching head,
On human woe her steady eye she turns,
Waves her meek hand and sighs for science dead,
For Science, Virtue, and for Small she mourns.

It is not, perhaps, great poetry, but it illustrates the connection, through Small and Franklin, between Jefferson, James Watt, Boulton and Darwin; between the destiny of the United States, the steam engine, modern industrialism, and the theory of evolution.

Franklin's part in the introduction of Small, and hence Watt, to Boulton, which led to the introduction of steam power into industry, and the beginning of the contemporary age, is a characteristic example of the operation of his insight. He could perceive better than any other man of his time which things had significance for the future.

5

Boswell has described the occasion when he drew Johnson's attention to Franklin's definition of man.

Boswell : " I think Dr. Franklin's definition of *Man* is a good one—' A tool-making animal.' "

Johnson : " But many a man never made a tool; and suppose a man without arms, he could not make a tool."

These two opinions summarize the difference between two stages of civilization. Franklin's definition contains the basis of anthropological and social science. Comparative anatomists have shown that the evolution of the brain has been stimulated by the co-ordination of functions necessary for the successful handling of tools. If man had not invented tools he would not have developed as good a brain. If his brain had been less good, his moral and philosophical achievements would have been less.

Franklin's definition is scientific, as it is made in terms open to all observers. No definition of man which includes references to private qualities unobservable by anyone except himself is scientific. John B. Watson could claim Franklin as a behaviourist.

The recognition of the importance of the tool is the key to sociology. The tool is the parent of the machine. It is the producer of goods, and hence of property. The behaviour of human society is conditioned by the system of the distribution of property. Law consists largely of rules by which property is distributed, as historians such as Coulton have remarked. Civilization is produced by tools. Experimental science is conducted with the assistance of tools in the form of instruments. Theoretical science is conducted with pencil, paper, and symbols, also forms of tools.

Concepts essential for the interpretation of the nature and history of man are implicit in Franklin's definition. It is a perfect expression of the modern spirit.

Johnson's comment exhibits the reaction of a pre-scientific tradition ; of a mind whose training had been restricted to theology, literature and scholasticism. It seems to belong to centuries before the Renaissance, yet Johnson was three years younger than Franklin. The younger man could have thundered comfortably with Augustine ; the elder would have been at ease with Pavlov.

6

Franklin showed the usual American interest in genealogy. He had compiled a complete account of his ancestors from the middle of the sixteenth century.

The American interest in genealogy probably started from the pioneers' memories of their home country. Their relatives in Europe were inaccessible. As they could not easily go to see them, they thought about them more. " Absence makes the heart grow fonder."

When the country was first settled, no aristocracy was in existence, because there was no civilized population. The pioneers started to make an aristocracy by the criterion of early arrival of ancestors. The search for ancestors in the *Mayflower* stimulated the study of genealogy.

The introduction of negro slavery gave another strong stimulation to genealogical studies. Large numbers of persons wished to prove themselves entirely white.

The wide American interest in genealogy has probably provided an important part of the foundation for the American achievements in the science of genetics. The present leaders of world-research on genetics and heredity are Americans such as T. H. Morgan and H. J. Muller.

Modern studies of human heredity give a slight suggestion of the origin of Franklin's extraordinary ability. Like his father, grandfather, great-grandfather, he was a youngest son. L. T. Hogben[1] has remarked that the statistics of mental ability and defect in London children show that "relatively bright and defective children tend more often to turn up late in the family group. As regards the scholarship children, the significance of this may reside in the possibility that the most favourable social environment for a child is an environment composed of other children."

Franklin belonged to the fifth generation of a series of persons all possessing an extra chance of being bright, owing to their late position in their respective family groups. The five extra chances may all have combined in his favour. The suggestion is speculative, but perhaps not entirely without significance.

The colonization of America put a series of vast biological problems to the early settlers. They knew how to cultivate the various crops, such as wheat, under European conditions, but they had to learn by experiment how to adapt them to American conditions. They also found a highly developed native agriculture, with native plants such as maize, already in existence. Bogart states that the American Indians had bred plants such as maize, beans and squashes, very far from the wild original types, and had given them a wider range in climatic adaptation than any comparable plants of the Old World. Carrier estimates that at least one-third of present American agriculture is based on the agricultural inventions of the native Americans before the European invasions.

The Indian method of cultivating maize was horticultural rather than agricultural. The difference of this technique and plant from those of the Old World was striking. European plants and animals introduced into America grew and behaved differently in the new environment.

These circumstances were another spur to American biology, and help to explain its present excellence.

Franklin was interested in the introduction of new crops and plants. He introduced the rhubarb plant, and continually supplied information about rice, silk-worm mulberry trees, and other plants.

The extension of empire by the colonization of North America did not have the same effect on biology as the extension by the conquest and government of less advanced peoples. In North America the settlers had to solve new problems in practical biology, but in India and elsewhere the conquerors had merely to drive and extend a native system that already existed, and extract from it profits to be spent in Europe. The conquerors of subject races are not directly interested in practical biology because they do not work on the land themselves. The divorce between government and technique is one of the causes of the decline of slave and pseudo-slave states.

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[1] *Genetic Principles in Medicine and Social Science.*

7

Two of the most remarkable American scientists have been intimately connected with communications. Franklin was connected with the American postal system for more than half his life, and became deputy postmaster-general.

Edison became a telegraphist when he was a youth, and his first important invention was an improvement of an electric telegraph instrument. Both of these men travelled considerably in connection with their postal and telegraphic work. Franklin first became interested in electricity during such a visit to Boston.

His influence with the post was essential to the success of his newspapers and journalism, for the postal connections put him at the centre of the arrival of news.

The continual receipt of news is stimulating to the inquiring and observant mind; and the psychological and practical characteristics of communication provide fertile material for the scientific imagination.

The development of communications encourages new types of political genius. It enables politicians without oratorical gifts to exert influence through journalism and letter-writing. Franklin and Jefferson are notable examples. In earlier ages, when public speaking was the chief mode of communication, they would have had far less political influence because they were poor speakers.

8

Faÿ has shown that Franklin was deeply influenced by the theories of the British Pythagoreans. When he was about sixteen years old he happened to find a book written by Tryon, who belonged to that group. Franklin writes that he was converted by Tryon to vegetarianism. It appears that he adopted the theory of metempsychosis from the same source. He may have met some of the British Pythagoreans during his first visit to London, and have acquired a stronger belief in their tenets through discussion with them. He composed a

Pythagorean epitaph in 1728, at the age of twenty-three, shortly after his first return from London, and sixty-two years later he willed that it should be inscribed on his tomb, unchanged.

THE BODY
OF
BENJAMIN FRANKLIN
PRINTER
(LIKE THE COVER OF AN OLD BOOK
ITS CONTENTS TORN OUT
AND STRIPT OF ITS LETTERING AND GILDING)
LIES HERE, FOOD FOR WORMS.
BUT THE WORK SHALL NOT BE LOST
FOR IT WILL (AS HE BELIEVED) APPEAR ONCE MORE
IN A NEW AND MORE ELEGANT EDITION
REVISED AND CORRECTED
BY
THE AUTHOR

Franklin believed that new and more elegant editions of his personality would be issued for ever. This is a version of the Pythagorean belief that when the body dies the soul finds a new habitation in a new human or animal body. Pythagoreans were vegetarians partly to avoid the risk of eating the present habitation of a soul that previously had inhabited a human body.

The importance attached to number and science by the Pythagoreans probably strengthened Franklin's interest in science.

His acceptance of metempsychosis, or transmigration of souls, familiarized him with the notion of things which passed through endless transformation and yet remained indestructible. It prepared his mind for acceptance of the principles of the conservation of matter, and a crude form of the conservation of energy. His ideas on the conservation in nature are advanced for his day.

Metempsychosis predisposed him to conservation. Study of nature confirmed his belief in conservation, and then in later life he began to quote the conservation of matter in support of the metempsychotic beliefs acquired in his youth.

He deduced the probability of human immortality by analogy from the conservation of matter. He wrote in 1785 that he observed great frugality in God's works. Compound substances are continually reduced to their elements, and their constituents used over and over again, and the same species of animals and plants continually populate the world, so God is without the " trouble of repeated new creations."

" I say that when I see nothing annihilated, and not even a drop of water wasted, I cannot suspect the annihilation of souls, or believe that he will suffer the daily waste of millions of minds ready made that now exist, and put himself to the continual trouble of making new ones. Thus finding myself to exist in the world, I believe I shall, in some shape or other, always exist."

The scientific notions of the conservation of matter and energy are to a large degree products of trading and industrial civilizations. In the processes of exchange and manufacture things are continually transformed, yet the products remain. The higher forms of steam and electric machinery cannot be properly designed without an exact knowledge of the transformations of matter and energy, so the modern principles of the conservation of matter and energy come to be exactly established when the demand for refined engine design has become urgent.

The analogies between the notion of the conservation of matter, which is such a characteristic philosophical product of industrial civilizations, and the metempsychotic ideas of the Pythagoreans suggest that Pythagoras himself had close connections with a trading and industrial civilization. It would be interesting to see what might be deduced concerning the trading and industrial features of the Greek society to which Pythagoras' sect belonged from the metempsychotic features in Pythagoras' philosophy.

As Faÿ remarks, Franklin's views on religion are related to Pythagoreanism and Freemasonry. Parton has suggested that Franklin in his youth acquired a belief in the possibility of subordinate gods who superintended the revolutions of the heavenly bodies from Isaac Newton, through conversations with Pemberton, Newton's disciple, about 1726.

In 1790, a month before he died, he answered a friend's queries concerning his religion.

" It is the first time I have been questioned upon it. But I cannot take your curiosity amiss, and shall endeavour in a few words to gratify it. Here is my creed. I believe in one God, the creator of the universe. That he governs it by his providence. That he ought to be worshipped. That the most acceptable service we render to him is doing good to his other children. That the soul of man is immortal, and will be treated with justice in another life respecting its conduct in this. These I take to be the fundamental points in all sound religion, and I regard them as you do in whatever sect I meet with them.

" As to Jesus of Nazareth, my opinion of whom you particularly desire, I think his system of morals and his religion, as he left them to us, the best the world ever saw or is like to see ; but I apprehend it has received various corrupting changes, and I have, with most of the present dissenters in England, some doubts as to his divinity ; though it is a question I do not dogmatize upon, having never studied it, and think it needless to busy myself with it now, when I expect soon an opportunity of knowing the truth with less trouble. I see no harm, however, in its being believed, if that belief has the good consequence, as probably it has, of making his doctrines more respected and more observed ; especially as I do not perceive that the Supreme takes it amiss, by distinguishing the unbelievers in his government of the world with any peculiar marks of his displeasure."

He was opposed to direct attacks on religion. He left the draft of a letter to a correspondent who had argued in favour of atheism. He wrote that the author should remember that while he might live a virtuous life without religion, the many weak and ignorant men and women require religion to restrain them into virtuous conduct until it becomes habitual. For this reason, an atheist might be indebted to an early religious education, which it would not be decent to spurn later.

" For among us it is not necessary, as among the Hottentots, that a youth, to be raised into the company of men, should prove his manhood by beating his mother."

9

After Franklin finally returned to America he considered the condition of some of the institutions he had founded. He had started the Philadelphia Academy in 1749 as a high school for youths. He had proposed, partly under the influence of Locke, that the courses of instruction should be based on English literature, with emphasis on the cultivation of good habits of reading and pronunciation. His scheme has interesting resemblances to the course of instruction that Faraday devised for himself. Faraday based his own education on the writing of English, and elocution.

Franklin was annoyed to find in 1789 that his Academy had degenerated into an old-fashioned classical school, in which the dead languages had been made the chief subjects, and the teacher of Latin the rector, at a much higher salary than the teacher of English.

It happened that Kinnersley, the teacher of English, was a talented man, who had given Franklin valuable assistance in his electrical researches, and had toured America and the West Indies, lecturing and demonstrating the new knowledge.

If Kinnersley had been made the rector of the Academy, he might have helped to give an early valuable modern impress to American education. The snobbery and blindness of the upper classes of Philadelphia prevented this, for they wished that their children should be taught Latin, because of its social prestige in Europe. The adoption of Latin in the early American high schools was reactionary and tended to put the new American governing classes under the intellectual influence of Europe, while they were struggling for economic independence. It indicated that they had no fundamental philosophical quarrel with Europe. They did not wish to disown the principles of European society, except in so far as they interfered with their own possession of power in America. This produced a conflict which is seen in men such as John Adams, who regarded the ancient learning of Europe as the natural source of knowledge, and yet fought against Europe economically and politically. In spite of his greatness, Adams never lost a petulance which resembles that of an undergraduate who has revolted against the university whose intellectual authority he accepts.

American Latinism helped to establish the authority and influence of American lawyers, which has contributed to the conflict between the pre-Renaissance spirit of American law with the modern spirit of American technology and science.

10

Swift complained that " a usurping populace is its own dupe, a mere under-worker, and a purchaser in trust for some tyrant, whose state and power they advance to their own ruin . . . in their corrupt notions of divine worship, they are apt to multiply their gods ; yet their earthly devotion is seldom paid to above one idol at a time, of their own creation, whose oar they pull with less murmuring, and much more skill, than when they *share the leading*, or even *hold the helm.*"

The condition of the world in the second quarter of the twentieth century offers much evidence for Swift's opinion. He had a low estimate of human nature. But he also shared the common opinion of his time, that the condition of men could be improved only by a reorganization of the balance of power between the classes. Franklin was not so pessimistic of humanity, nor did he attach much weight to the conception of history as a complex of interacting class forces. He was an experimentalist, and inclined to believe that much was to be discovered by experiment about human beings and the science of politics. This view was valuable, especially as an indication of the direction in which humanity might gain more political knowledge. He was conscious of the limitations of the theorists of the Madison school, who, like Swift, conceived history as a mechanical circus activated by the forces of conflicting social classes. These theorists were the American heirs of the theorists of the English mercantile classes. They assumed that the chief motive forces of history were known, and that nothing more of primary importance was to be discovered by sociologists. As an experimentalist, Franklin could not accept that. His dislike of this view prevented him from appreciating its analytical value. The notion of history as a balance of social forces will give much insight into the nature of the social or political position at any moment, but in the form in which it was accepted in Franklin's time, it was not suggestive of the new forces and positions that might be expected to appear in society in the future.

Franklin's failure as an analyst of social conditions is shown by his surprise at the French Revolution. He had lived in France for ten years just before the Revolution, with extraordinary opportunities for receiving information about the social tendencies of the people, and completely failed to comprehend the portents.

On November 2nd, 1789, he wrote: "The revolution in France is truly surprising. I sincerely wish it may end in establishing a good constitution for that country. The mischiefs and troubles it suffers in the operation, however, give me great concern."

11

Franklin's weakness and strength as a social philosopher were illustrated by his rejection of the conception of history as a balanced interaction of social forces. He could not be contented with a conception that did not include the possibility of the incursion of new factors into history. He disliked the notion of society as a machine that went round and round for ever, without arriving at any new place. Though his rejection of this conception limited his power of social analysis, his belief in experiment and novelty gave him a freedom in interpretation that had some of the advantages of an evolutionary conception of social history. This enabled him to make contributions towards the escape of humanity from the apparently closed circles of historical change.

If the people are to avoid the tendency noted by Swift of appointing dictators over themselves, they must learn that better possibilities exist. They must acquaint themselves with the possibilities of society and nature, and gain some general idea of the system and tendencies of the forces that govern society. Franklin's particular genius was for the first part of this task. No one was more sensitive to new knowledge, and had greater power of explaining it to the people. He was a philosophic journalist. He put a vast range of human knowledge within the reach of the people. Until the people have knowledge they will not know how to avoid dictators.

Modern civilization was produced by the subdivision of labour and the rise of the specialist. The limitation of the specialist is one of the greatest dangers to society. He tends to exaggerate the importance of his specialty, and to underrate other knowledge. He is naïve on matters outside his subject, and liable to be misled on these by charlatans. He may be protected from deception only by continued broad education during adult life.

As adults will not go to schools for the whole of their lives they must learn through other agencies. The most important is philosophic journalism, in which the general ideas of new knowledge are explained to uninformed persons of adult intelligence. Franklin was one of the first and greatest of the philosophic journalists, whose existence became necessary through the growth of specialization. At the present time, H. G. Wells is a distinguished member of the same class, Both have optimism and love of novelty, and both are weakest in analysis of historical forces.

Specialization enhances individual naïveté, and hence the danger of the rise of dictatorships. The antidote for specialization is the universalism of the philosophic journalist. Franklin is the grandest example of a social type essential to the advance of modern society.

The ability with which he employed journalism is unequalled. As Adams peevishly observed, he made himself the most famous man of his generation. "His name was familiar to government and people, kings, courtiers, nobility, clergy, and philosophers, as well as plebeians, to such a degree that there was scarcely a peasant or a citizen, a *valet de chambre*, coachman or footman, a lady's chamber-maid or a scullion in a kitchen, who was not familiar with it, and who did not consider him as a friend to human kind."

Adams writes that his reputation was more universal than that of Leibnitz, Newton, or Voltaire, and he was free from the hatred that cancelled the adoration for Louis XIV, Frederick, and Napoleon.

Adams explains that "He had been educated a printer, and had practised his art in Boston, Philadelphia, and London for many years, where he not only learned the full power of the press to exalt and to spread a man's fame, but acquired the intimacy and the correspondence of many men of that profession, with all their editors and many of their correspondents. This whole tribe became enamoured and proud of Mr. Franklin as a member of their body, and were consequently always ready and eager to publish and embellish any panegyric upon him that they could procure. Throughout his whole life he courted and was courted by the printers, editors, and correspondents of reviews, magazines, journals, and pamphleteers, and those little meddling scribblers that are always buzzing about the press in America, England, France, and Holland."

Franklin performed his task as a philosophic journalist, an educator of the adult members of democracies, with prodigious skill, and thereby acquired an equal fame.

With his fame and skill he helped to split a reactionary British Empire, and secure an independent United States of America.

As scientist, journalist, and diplomat he exhibited an unparalleled combination of great abilities. Neither America nor England has since produced his equal as a universally developed human being.

II

LIFE AND RESEARCHES

1. EARLY LIFE

FRANKLIN has written a famous autobiography and numerous letters, pamphlets, and articles, of which about fifteen thousand are extant. As he discussed a vast range of interests in a simple and fascinating style, his writings provide one of the most expressive accounts of a personality. Few geniuses of his degree have possessed a style intelligible to an almost universal public. General influences, including the readability of his writings and the incidents of his career, made him very famous. Many of his contemporaries did not understand him well, and during the nineteenth century his reputation declined. No man will ever be completely comprehended by himself, his contemporaries, or his successors, but the passage of time brings out some perspectives less visible in his own day. Time abets the collection of facts. In the twentieth century many important new details about Franklin have been collected by scholars such as A. H. Smyth and Bernard Faÿ. These circumstances assist a better comprehension of the significance of Franklin in the history of civilization since the Renaissance.

Benjamin Franklin was born at Boston, Massachusetts, on January 17th, 1706. His father, who had left England in 1682 to escape from religious persecution, had strong sense, health, and sociable habits, and died at the age of eighty-nine years. His second wife bore him ten children, of which Benjamin was the youngest boy, and died at eighty-five years. Franklin was the fifth of five generations of youngest sons. As he was the tenth [1] son his father wished him to become a priest. He had already shown facility in learning. He had "an exceedingly good memory," but could not remember when he learned to read, so he must have learned very early. He was sent to a grammar school at eight years of age to begin education for the church, but left after one year. His father decided he could not afford the expense of a clerical training, so he sent him to a modern school qualifying pupils for trade and practical careers.

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[1] Faÿ states he was the ninth.

Faÿ suggests the economical spirit which prompted Franklin's father not to spend money on education for a learned profession was the formative psychological influence of Franklin's life. When Franklin was an infant, he bought an attractive whistle for an excessive price. His father, with his economical spirit, laughed at him for being swindled. According to Faÿ, this left a psychological complex which never faded from his mind, and gave a utilitarian shape to his character.

He left the second school at the age of ten. His father had been a dyer in England, but could not make the trade pay in America, and had become a tallow-candle maker. Benjamin assisted him in his work, but hated it, so his father tried to discover his aptitudes by taking him to watch mechanics and carpenters at work. Franklin records that " It has ever since been a pleasure to me to see good workmen handle their tools ; and it has been useful to me, having learned so much by it as to be able to do little jobs myself in my house when a workman could not readily be got, and to construct little machines for my experiments, while the intention of making the experiment was fresh and warm in my mind." Near the end of his life he refers to his love of hammering and carpentering in the bequest of a box of nails to one of his French philosophic friends.

His father finally decided to make him into a printer because he showed a taste for reading. Franklin records that he read Bunyan, R. Burton, Plutarch, Defoe, Locke, and Cocker's Arithmetic. He was apprenticed to his elder brother, who printed the second newspaper to appear in America. About 1721 he studied an odd volume of the *Spectator*. He trained himself to write by reading this work, making notes of the various points in the essays, or turning them into verse, putting them away, and then re-writing the essays from the notes or verses. He compared his versions with the originals, and observed where they were inferior, and also, in some small points, he writes, where they were superior.

His brother had learned printing in London. He returned to Boston and started a radical paper, under the influence, according to Faÿ, of temperament, youth, consciousness of knowledge of superior culture from the capital city, and the absence of opening for a conservative paper. He ran the paper by attacking the conservatives. One of these was Cotton Mather, who had enthusiastically introduced the technique of inoculation against smallpox within two months of the communication of it to Europe by Lady Mary Wortley

Montagu. As Faÿ remarks, the Conservatives, such as Mather, were prepared to try things they could not understand, while the Liberals, Whigs and rationalists were not. Franklin now was fifteen years old, and assisted in the attacks. Years afterwards he lost his favourite son through neglecting to have him inoculated, and he regretted his early attacks on what proved to be good science.

He wrote a number of articles, the "Dogood Papers," in imitation of *Spectator* essays, and sent them anonymously to his brother's paper, which he was himself helping to print. They had much success, but his brother became jealous when he discovered their authorship, and began to bully him, so he ran away to Philadelphia. Franklin attributed his aversion to arbitrary power to this conflict with his brother. Faÿ suggests he was in turn jealous of his brother's superior knowledge of the world and women, and that this also determined him to acquire equal experience.

He became a vegetarian at the age of sixteen. According to Faÿ, he learned vegetarianism from the works of Tryon, an English Pythagorean. He learned the notion of metempsychosis from the same source. Faÿ explains that the notion of metempsychosis had a profound influence on his thought. It is implicit in his epitaph, quoted on page 29. This was written in 1728, and by his will inscribed on his tomb. He found the vegetarian diet economical. It helped him to save money to buy books, and gave him quiet dinner hours, when he could read and meditate alone in the printing shop, while his colleagues had gone to their heavy dinners. His bookishness did not conflict with his health. He was a powerful swimmer, and sometimes drifted for hours in lakes, towed by the string of a kite.

He found work as a printer in Philadelphia. His enterprise and writing talent were noticed by the governors of Pennsylvania and New York. The first of these, Keith, encouraged him to set up his own business, and suggested he should go to England to choose the types. Keith promised to give him letters of introduction to personages in London. Franklin and his friend Ralph, a writer of lively talent but superficial character, sailed before they discovered that the governor, according to Franklin, was one of those men who try to secure popularity by giving more promises than they can keep. Faÿ writes that Keith was unable to help Franklin owing to more creditable reasons. He was intelligent and radical, and introduced paper money, which greatly helped the community. His advanced policy made him enemies, and the absorption in his struggles against them prevented him from giving more help to Franklin.

When the friends arrived in London, they had to find work as soon as possible, instead of buying equipment for a printing shop in America. Franklin was not yet nineteen years old. He immediately got work at an important printer's named Palmer, and presently had to compose the second edition of Wollaston's *Religion of Nature*. He disagreed with some of the reasonings, and wrote and printed a little pamphlet concerning them, entitled *A Dissertation on Liberty and Necessity, Pleasure and Pain*. A surgeon named Lyons noticed it, and sought Franklin's acquaintance, and took him to a club of which Mandeville, the author of the *Fable of the Bees*, was the leader. Lyons introduced Franklin to Pemberton, the editor of the third edition of Newton's *Principia*, the printing of which was begun about the end of 1723, and finished in 1726. Franklin very much desired to see Newton, and Pemberton promised him the opportunity, but this never occurred. Newton died in 1727.

Franklin discovered an old lady who was willing to board him for thirty cents, or one shilling and sixpence, per week. She enjoyed his company and approved his regular habits. He did not drink while at work, and was given the most urgent, best-paid jobs, because he was never absent or blue on Mondays.

Franklin has left numerous accounts of his ingenious personal economies and abstemiousness. His creed of self-help acquired for him much of his popular fame. Yet in his old age he wrote " Frugality is an enriching virtue ; a virtue I never could acquire myself ; but I was once lucky enough to find it in a wife, who therefore became a fortune to me."

While in London he taught two of his friends to swim in two lessons. This came to the notice of some gentlemen during a visit to Chelsea, so Franklin stripped and leaped into the river to demonstrate his abilities. He swam to Blackfriars, a distance of more than three miles, " performing on the way many feats of activity, both upon and under the water." After this performance he was advised to open a swimming school.

His friend Ralph became intimate with a milliner. He owed money to Franklin, and had to leave London to obtain work, and commended the milliner to his protection. Franklin tried to seduce her, but was repulsed. Ralph considered the incident cancelled his debts to him.

At the beginning of the eighteenth century the intellectual and social life in London was radical, progressive, and vigorous. The triumph of the mercantile classes, represented by the dethronement of James II in 1689, was being spiritually consummated. Franklin lived in this atmosphere while he was of student age, and before his mind had become set. He returned to America with the knowledge and the optimism of the ideology of a new governing class. Freemasonry was one of the new social movements arising out of mercantilist social ideas. It was growing rapidly and spreading to other countries. Franklin was immediately attracted by a movement so expressive of the spirit of the period.

Franklin had strong passions. He records that before he was married in 1730 the " hard-to-be governed passion of youth hurried me frequently into intrigues with low women that fell in my way, which were attended with some expense and great inconvenience, besides a continual risque to my health by a distemper which of all things I dreaded, though by great good luck I escaped it."

A. H. Smyth writes that the Franklin manuscripts in the Library of Congress include letters to young women at home and experienced matrons abroad, which contain passages too bawdry to " be tolerated by the public sentiment of the present age " (1906). He considers Franklin remained to the end of life a proletarian in spirit, the descendant of hard-handed blacksmiths, and possessed of " strong and rank " " animal instincts and passions."

His wife was Deborah Read, to whom he had been betrothed before he went to England. He had deserted her, and had married her afterwards, partly from pity and duty.

Franklin returned to Philadelphia after spending eighteen months in London. At first he was unable to find work except with Keimer, his former employer. After some manœuvres he succeeded in starting a printing business with a partner.

About the same time, he formed the Junto club, for intellectual discussions among his friends. This club persisted for forty years. Its membership was restricted to twelve, and the subjects of discussion included ethical questions such as " Is self-interest the rudder that steers mankind ? " ; " Does the importation of servants increase or advance the wealth of our country ? " ; " Whence comes the dew, that stands on the outside of a tankard that has cold water in it in the summer time?"—ethics, political economy, and natural philosophy.

Keimer had been forced to re-employ Franklin because he had obtained a profitable contract to print paper money for the province of New Jersey, and Franklin was the only person in America who could make copper plates for printing notes. Having seen there were profits for a printer in printing paper money, Franklin discussed the principles of paper money with his Junto friends and wrote a pamphlet entitled *A Modest Inquiry into the Nature and Necessity of a Paper Currency*. Under the influence of Governor Keith and this pamphlet Pennsylvania decided to print paper money and Franklin received the profitable contract. He remarked that the common people were in favour of paper currency and the rich against, but the rich had no adequate exponent of their views.

In the course of the argument concerning the nature of money Franklin writes: "as silver itself is of no certain permanent value, being worth more or less according to its scarcety or plenty, therefore it seems requisite to fix upon something else more proper to be made a *measure of values*, and this I take to be *labor*."

Wetzel suggests that Franklin learned the notion of the labour theory of value from Sir William Petty's *Essay on Taxes and Contributions*. Franklin also gives a definition of natural interest on capital. He assumes that rent is the most secure form of interest, and that interest on capital should be equal to that rate, plus an increase proportional to the difference in risk between the investment of the capital in land and in any project.

On May 19th, 1731, he made some notes on his reading of history.

"That the great affairs of the world, the wars, revolutions, etc. are carried on and effected by parties."

The parties follow their immediate interests, which produces the usual confusion of social affairs. As soon as a party gains its point, its members become intent on their particular interests. Few public men act "from a meer view of the good of their country."

Franklin considered founding a United Party for Virtue, whose membership should be restricted to young and single men. Its principles were to resemble those of the Freemasons.

He founded the first subscription library in America in

1730, to assist the reading of his friends in the Junto, and contribute to the general education. The library secured through one of the members of the Junto an influential patron : Peter Collinson, an eminent Quaker connected with the Penn family, and a distinguished botanist. From 1730 until 1768, when he died at the age of seventy-five, Collinson helped to collect and send books for the library, and accounts of the most recent discoveries in agriculture, arts, and science. Franklin writes that Collinson sent an electrical machine and an account of the German experiments on electricity in 1745 (he acknowledged the receipt of the machine in 1747). This stimulated his interest in electrical experiments, and Collinson's friendly reception of his letters describing his results encouraged him to proceed with his researches.

The library was imitated throughout the American colonies, with important results. Mrs. John Adams noted at the beginning of the nineteenth century that the common people of America were, on the average, far better informed than those of England.

He introduced *Poor Richard's Almanac* in 1733. He " filled all the little spaces that occur'd between the remarkable days in the calendar with proverbial sentences, chiefly such as inculcated industry and frugality, as the means of procuring wealth, and thereby securing virtue."

At this date, almanacs were of great importance. They contained notices of the chief holydays, market days, and other events of the year. They were essential to farmers, shopkeepers, and craftsmen. Many homes possessed only two books : the Bible and an almanac. Franklin adopted the traditional style of the almanacs, but improved it by his superior understanding and literary expression of the proverbial philosophy of the masses. *Poor Richard's Almanacs* had a wide sale in America, and were translated into many languages. They established Franklin's fame among the masses, and are his most effective literary works. The success of *Poor Richard* was not due entirely to Franklin's literary skill and psychological insight. His *Poor Richard* rode on a scientific horse, as almanacs are records of time. L. T. Hogben and other writers have commented on the profound influence of the construction of almanacs on the cultivation of science. Early astronomy was created in order to construct almanacs for the control of agriculture and the processes of human society. Franklin's understanding of the importance of the sequences of nature was connected with his aptitude for science. Almanacs gave scope to the scientific besides the literary aptitudes of his mind.

In the same year he made a partnership with one of his printers, to start a printing-house in Charleston. He provided one-third of the capital, and took one-third of the profits. He extended this system of holding capital in various businesses, and, according to Phillips Russell, invented the American trust. He attributed much of the success of the scheme to the care with which the deeds of partnership were devised.

He published *Constitutions of the Free Masons* in 1734, and an essay "On the Usefulness of Mathematics" in the *Pennsylvania Gazette*, in 1735. He remarks that no business or commerce can be managed or carried on without numbers, and geometry is essential for mariners, architects, engineers, and geographers.

He became clerk to the General Assembly of Pennsylvania in 1736, and postmaster of Philadelphia in 1737; "tho' the salary was small, it facilitated the correspondence that improv'd my newspaper . . . as well as the advertisements."

He began to turn his thoughts to public affairs, and among other projects founded a fire-brigade, the Union Fire Company.

The preacher Whitefield arrived in America in 1739. Franklin writes: "I had the curiosity to learn how far he could be heard, by retiring backwards down the street towards the river; and I found his voice distinct till I came near Front-street, when some noise in that street obscur'd it. Imagining then a semicircle, of which my distance should be the radius, and that it were fill'd with auditors, to each of whom I allow'd two square feet, I computed that he might well be heard by more than thirty thousand. This reconceil'd me to the newspaper accounts of his having preach'd to twenty-five thousand people in the fields, and to the antient histories of generals haranguing whole armies, of which I had sometimes doubted."

Franklin acquired Whitefield's friendship. Faÿ suggests that this enabled him to secure the preacher's demagogic gifts in aid of his own popularity. His rational mind could not appeal to mob emotions, but Whitefield could appeal to them on his behalf. In some degree he used the preacher as his lieutenant of the mob.

Franklin maintained relations with Whitefield for many years. He discussed with him methods of influencing the people, and other problems concerning the arts of salvation and government. He wished to learn from him the psychology of the herd, and how it should be applied. In a letter to Whitefield, written in 1749, he quotes the view of Confucius, that peoples should be reformed by converting the grandees. When this is done, the masses follow by imitation. "The mode has a wonderful influence on mankind ; and there are numbers who, perhaps, fear less the being in hell, than out of the fashion. Our most western reformations began with the ignorant mob ; and when numbers of them were gained, interest and party views drew in the wise and great. Where both methods can be used, reformations are likely to be more speedy. O that some method could be found to make them lasting ! He who discovers that will, in my opinion, deserve more, ten thousand times, than the inventor of the longitude."

Franklin proposed the foundation of the first American Philosophical Society in 1743. The Philadelphia members were to include a physician, botanist, mathematician, chemist, mechanician, geographer, and general natural philosopher, besides a president, treasurer, and secretary. He offered himself as secretary. The Society was to promote Useful Knowledge. This is in contrast with the purpose of the Royal Society of London, which was founded to promote Natural Knowledge. The differences in aim show that the two societies were founded on behalf of different social classes, one a leisure class and the other a tradesman's class.

He published an account of a new sort of fireplace in 1744, which he had invented in 1742. He refused to patent it because " we enjoy great advantages from the inventions of others, we should be glad of an opportunity to serve others by any invention of ours."

As colonization proceeded in the Eastern states, wood-fuel became more expensive. Franklin designed a more economical stove, which created enough draught to ventilate the room adequately, and heated enough air to warm the room evenly by convection, and yet allowed a sight of the fire.

He afterwards elucidated the movements of air in chimneys, and explained that the air flowed up or down according to differences in temperature. In the summer, food could be kept fresh by covering it with a wet rag and putting it in the chimney, where the air current made the water evaporate, and so cooled the food.

There were many wars in Europe and America in 1745. Exposed ports such as Boston feared attacks, and their populations were active in military preparations for defence and counter-attack. During a visit to Boston in 1746 Franklin acquired the military fervour and returned with it to Philadelphia. Many persons in Pennsylvania were nervous over the inadequate defences, owing to the influence of the pacifist Quakers in the provincial government. Franklin proposed the formation of a militia, and artfully persuaded the Quakers not to oppose it.

He wrote an enthusiastic letter to his brother at Boston, and suggested the Americans should succeed in their attack on Cape Breton because "five hundred thousand petitions were offered up to the same effect in New England, which, added to the petitions of every family morning and evening, multiplied by the number of days since January 25th make forty-five millions of prayers ; which, set against the prayers of a few priests in the garrison, to the Virgin Mary, give a vast balance in your favour."

During his visit to Boston, Franklin happened to meet a Dr. Spence, who had just arrived from Scotland, and had brought some apparatus for making experiments with statical electricity. Franklin was fascinated by the apparatus, though it did not work very well, for Spence did not know how to use it properly.

In 1747 Peter Collinson included an electrostatic machine with one of his parcels of books for the library company. On March 28th, 1747, Franklin acknowledged the gift in a letter to Collinson :

Sir,

Your kind present of an electric tube, with directions for using it, has put several of us on making electrical experiments, in which we have observed some particular phaenomena, that we look upon to be new. I shall therefore communicate them to you in my next, though possibly they may not be new to you, as among the numbers daily employed in those experiments on your side the water, 'tis probable some one or other has hit on the same observations. For my own part, I never was before engaged in any study that so totally engrossed my attention and my time as this has lately done : for what with making experiments when I can be alone, and repeating them to my Friends and Acquaintance, who, from the novelty of the thing, come continually in crouds to see them, I have, during some months past, had little leisure for any thing else.

I am, &c.

B. Franklin.

Within a few months Franklin and his friends discovered facts and conceptions which transformed the theory of statical electricity. This was an important contribution to the modernization of the human concepts of nature.

2. ELECTRICAL RESEARCHES

The distinction of Franklin's contributions to the science of electricity becomes clear when his work is compared with that of his predecessors.

The first record of an electrical phenomenon occurs in the writings of Theophrastus in 300 B.C. He described how amber, when rubbed, attracted light bodies. Later writings state that Thales, who lived in 600 B.C., was familiar with this phenomenon, and deduced from it that amber is animated.

Nearly two thousand years passed before anything more was added to the knowledge of electricity. About 1600, William Gilbert of Colchester in England, a physician to Queen Elizabeth, proved that many other substances besides amber could be electrified. His list included diamond and several other real and imitation precious stones, glass, sulphur, and coloured sealing-wax. The science of electrostatics developed after the Renaissance partly because expanding trade provided a wider variety of materials for experiments. The materials of the early experiments on electrostatics sound like the stock of a shop ; diamonds, wax, silk, wool, linen, etc. Gilbert observed that electrified bodies would attract bits of wood, metal, stone, and drops of water and oil. Thick smoke was noticeably attracted but not thin smoke, air, or flames. He found that electrical effects were strongest when the air was dry and the wind blew from the north or east. Under these conditions electrified bodies would retain their charges for ten minutes. Moist air or southerly winds destroyed the electrification. He found that moisture of any sort, such as that carried in the breath, had the same effect. Sprinkling with brandy also destroyed electrification, but sprinkling with oil did not. He presented a drop of water on a dry substance to an electrified body, and observed that it was distorted into a conical shape. Gilbert asserted that magnetism exhibited attraction and repulsion but that electricity exhibited attraction only, and never repulsion. He supposed that electrical attraction is analogous to cohesion. Two drops of water brought into contact rush together. Similarly, an electrified body is surrounded by an effluvium which brings it into contact with the object it attracts, and makes them rush together.

These researches, and others on magnetism, were a wonderful advance in experimental science. They were an important inspiration to Galileo, who envied their author's achievements. The study of the electrical properties of the atmosphere and gases has led to several of the most fundamental advances in electrical science. The first student of electricity in modern times did not fail to observe the influence of the weather on electrification. L. Hogben has suggested that Gilbert's interest in magnetism was inspired by the desire of British navigators to find some new method of determining longitude. The Portuguese and Spanish navigators used Moorish astronomical methods for determining longitude which depended on the use of eclipses and occultations. With their aid Christopher Columbus discovered America. They were exact, but not useful to the English because they could not be easily used in cloudy northern latitudes.

The famous inventor of the air-pump, Guericke, was the next important contributor to the science of electricity. He invented the first electrical machine. This consisted of a sphere of sulphur which could be rotated on a shaft through its centre. The sphere was charged by rubbing it with the hand as it rotated. He discovered electrical repulsion, that two bodies bearing electricity from the same source repelled each other. He noticed electric sparks for the first time, and heard the associated sounds. He observed an effect due to electric induction, which was not appreciated for nearly a century.

Contemporary with Guericke, Robert Boyle discovered that electrical attractions may occur in vacua. He proved by experiment that attracted objects pull the electrified body as strongly as they are themselves pulled. Newton's law of the equality of action and reaction was not yet established.

Electric discharges were first compared with thunder and lightning by Wall, a friend of Boyle, about 1680. Wall published a description of the experiments which inspired this classical suggestion in the *Transactions* of the Royal Society in 1708. His paper, " On the Luminous Qualities of Amber, & cont.," was communicated to the Society by Sloane. Franklin met Sloane in 1726, during his first visit to London, and sold him a purse made of asbestos. Wall's paper contains three remarkable features. Boyle was interested in phosphorus, but disliked the usual method of preparing it, which consisted of evaporating urine. Wall searched for methods of manufacturing what appeared to be phosphorescence, and found that amber and other substances would apparently phosphoresce when rubbed. Indeed, amber would produce big flashes and cracklings, resembling lightning and thunder. He perceived the importance of the discovery, and forecast the event of a genius who would interpret it. Wall concludes his paper with the hope that his observations will commend him to posterity. Several passages are quoted, in order to illustrate the style of one of Franklin's predecessors, and Wall's own scientific talent, and nobility of mind.

" You may remember my telling you many Years ago of my good Friend Mr. Boyle's communicating to me, about the Year 1680, his way of making the Phosphorus with Urine, at the same time desiring me to use all my Endeavours to find out some other Subject, from whence it might be made in greater quantity, and perhaps he might have made the like Request to many more ; for, to use his own Words, he said, he really pitty'd his Chymist, who was forced to evaporate so prodigious a Quantity of Urine, to get a very little of the Phosphorus. Soon after, in order to see some Experiments in Chymistry, I lodg'd for a short time at his Chymist's House, one Mr. Bilgar, then living in Mary Le Bone Street near Piccadilly, who indeed was equally, if not more importunate with me than Mr. Boyle, to try if I cou'd find out some other Matter from which more might be made than from Urine, telling me there was so great a demand for it, that it wou'd be of very great advantage to him. It being then a very hot summer, I caused a piece of the dry'd Matter in the Fields, where they empty the Houses of Office, to be digg'd up, in which, when broken in the Dark, a great number of small Particles of Phosphorus appear'd. This Matter I carry'd to Mr. Boyle, who viewed it with great Satisfaction, and Mr. Bilgar, by his Direction, fell to Work thereon, but from it cou'd make very little or no Phosphorus, till another Matter was added to it in Distillation, and then he cou'd therewith make large Quantities, to his great Profit ; for while I was at his House, I often saw him make it, and sell it for six Guineas, and six Louis d'Ors an Ounce, whereby he got so much Money, that, I believe, he thought himself above his Business, and quickly left England ; so that we have lost an Honest and Industrious Chymist, and Mr. Boyle a Faithful and Industrious Servant. . . .

. . . " Now, Sir, my being, as you have heard, well acquainted with the Artificial Phosphorus, was the occasion of my making many Reflections about it, and caus'd me to consider, whether there might not be *in rerum natura* other natural ones, besides those that Mr. Boyle and some others have given an account of.

"You well know, Sir, that Humane Urine and Dung do plentifully abound with an Oleosum and Common Salt, so that I take the Artificial Phosphorus to be nothing else but that Animal Oleosum coagulated with the Mineral Acid of Spirit of Salt, which Coagulum is preserv'd and not dissolv'd in Water, but accended by Air. These Considerations made me conjecture that Amber, which I take to be a Mineral Oleosum coagulated with a Mineral Volatile acid might be a Natural Phosphorus, so I fell to make many Experiments upon it, and at last found, that by gently rubbing a well polished Piece of Amber with my Hand in the dark, which was the Head of my Cane, it produc'd a Light; whereupon I got a pretty large piece of Amber, which I caused to be made long and taper, and drawing it gently thro' my Hand, being very dry it afforded a considerable Light. I then us'd many Kinds of soft Animal Substances, and found none did so well as that of Wool. And now new Phenomena offered themselves; for upon drawing the piece of Amber swiftly thro' the Woollen Cloth, and squeezing it pretty hard with my Hand, a prodigious number of little Cracklings were heard, and every one of those produc'd a little flash of Light; but when the Amber was drawn gently and slightly thro' the Cloath, it produc'd a light but no Crackling; but by holding one's Finger at a little distance from the Amber, a large Crackling is produc'd with a great flash of Light succeeding it, and, what to me is very surprizing, upon its eruption it strikes the Finger very sensibly, wheresoever apply'd, with a push or puff like Wind. The Crackling is full as loud as that of Charcoal on Fire; nay five or six Cracklings, or more, according to the quickness of placing the Finger, have been produc'd from one single Friction, Light always succeeding each of 'em. Now I make no question, but upon using a longer & larger piece of Amber, both the Cracklings & Light would be much greater, because I never yet found any Crackling from the Head of my Cane, altho' 'tis a pretty large one; and it seems, in some degree, to represent Thunder and Lightning; but what to me is more strange than all I have been telling you is, that tho' upon friction with Wool in the daytime, the Cracklings seem to be full as many and as large, yet by all the Tryals I have made, very little Light appears, tho' in the darkest Room; and the best time of making these Experiments, is when the Sun is 18 Degrees below the Horizon; and when the Sun is so, tho' the

Moon shines never so bright, the Light is the same as in the darkest Room, which makes me chuse to call it a Noctiluca."

Wall concludes his paper, which was the only one he contributed to the *Philosophical Transactions*, with these noble words :

" I am not without hopes but that some more elevated and happy Genius may arise, under whose Conduct these hints may be carry'd on to a height not easie to be foreseen by Persons of short Views, whose Conceptions are confined within the narrow limits of what's already known, and whose Self sufficiency sooths 'em with a *Ne plus ultra.*

" Thus, Sir, I please myself with the remote prospect of new Scenes in Nature, which, tho' imperfect at present, may in time by some skilful Hand be finish'd and fitted for a nearer view, tho' before that time shall come, nothing may remain of me besides this Testimony of my good Will to Mankind, and particular respect for you."

Wall imagined he had observed a connection between the sparking of electrified amber and the position of the sun.

Isaac Newton made some electrical experiments about 1675. He discovered that electrified glass attracted light bodies on the side opposite to that which had been rubbed. This showed that electrical attraction might pass through a solid dielectric. He supposed that electrified bodies emitted an elastic fluid which freely penetrated glass, and that the emission was performed by vibrations of the constituent particles of the electrified bodies.

In 1670 Picard had observed an electric glow in vacua over mercury, and before the end of the century Italian experimenters of the " de Cimento " discovered that electrified bodies could be discharged by flames.

The ability of glass to take a high electrification was first observed by Hawkesbee, and described, with many other valuable observations, in his book on *Physico-Mechanical Experiments*, published in 1709. He whirled a hollow glass globe, which was electrified by rubbing with the hand. This machine was the forerunner of the glass electrostatic machines. He examined the various glows produced in the air within the globe, when the pressure of the air was varied. He observed that if the globe was filled with dry sand, its strength of electrification decreased. He found that the electrification of a solid cylinder of glass was slightly less, but more permanent, than that of a hollow cylinder. Thus he compared the properties of various dielectrics. Hawkesbee did not clearly distinguish between insulators and conductors. He supposed he could not electrify a metal because " all the attrition of the several bodies I have used for that purpose, have been too weak to force it from it." He believed that friction forced electricity out of bodies.

The progress of electrical research for the next quarter of a century was slow, probably owing to the failure of Hawkesbee's successors to adopt his electrical machine. Experimenters returned to the rubbing of rods, which did not provide them with powerful supplies of electricity, and hence increased the difficulty of their experiments. The incident is an instructive example of the results of neglecting large-scale experiments, and failing to take advantage of increased power provided by improvement of machinery.

This may have some connection with the arrest of scientific and technical development in the early eighteenth century, owing to the ease with which wealth was procured from India, according to the suggestion of G. N. Clark.

A remarkable series of experiments was made by Stephen Gray and his friend Wheeler about the year 1728. They discovered electricity could be conducted along threads of linen or hemp. They constructed lines of thread over a hundred feet long, supported by silk, and succeeded in detecting electricity that had passed from one end to the other.

" Mr. Wheeler was desirous to try whether we could not carry the Electrick Vertue horizontally. I then told him of the Attempt I had made with that Design, but without Success, telling him the Method and Materials made use of, as mentioned above. He then proposed a Silk Line to support the Line by which the Electrick Vertue was to pass. I told him it might do better upon the Account of its Smallness so that there would be less Vertue carried from the Line of Communication, with which, together with the apt Method Mr. Wheeler contrived, and with the great Pains he took himself, and the Assistance of his Servants, we succeeded far beyond our Expectation."

The silk was made as thin as possible, as Gray and Wheeler assumed that its conducting power depended on its thickness. The silk proved to be too thin to support the weight of the thread, so they tried other materials. They tried brass wire, because that could be both strong and thin. But the electricity would no longer pass down the thread, as it seemed to disappear into the brass wire. As the conduction did not appear to depend on thickness, they returned to the use of thicker silk. They found that hempen lines supported by loops of silk would conduct electricity some eight hundred feet.

Thus Gray and Wheeler discovered the distinction between conductors and non-conductors.

These ingenious experimenters studied the effects of electricity conducted on to lode-stones, red-hot pokers, chickens, and boys. Gray proved that liquids could be electrified by charging soap-bubbles.

" I dissolved Soap in the Thames Water, then I suspended a Tobacco-Pipe by a Hairline, So as that it hung nearly horizontal, with the Mouth of the Bowl downwards : then having dipped it in the Soap-Liquor, and blown a Bubble, the Leaf-Bras laid on a Stand under it, the Tube being rubbed, the Bras was attracted by the Bubble."

Gray was a brilliant experimenter, but had a peculiar temperament. In 1739, after Gray's death, Desagulier wrote that he had not entered on electrical researches because Gray, who had wholly turned his thoughts to electricity, " was of a temper to give it entirely over, if he imagined that any thing was done in opposition to him." Gray felt he had a proprietary right in electrical discoveries.

As experimenters in England were afraid of encroaching on Gray, it is not surprising that the next great advance occurred in France. Dufay discovered " that there are two distinct kinds of electricity, very different from one another ; one of which I call vitreous, the other resinous electricity. The first is that of glass . . . the second is that of amber. . . . The characteristic of these two electricities is, that they repel themselves, and attract each other. . . . From this principle, one may easily deduce the explanation of a great number of other phenomena ; and it is probable, that this truth will lead us to the discovery of many other things."

Dufay transmitted electricity over spaces of twelve inches of air, when a lighted candle was placed in the middle of the space.

He observed that when he insulated himself and was charged with electricity, sparks visible in the dark could be taken out of him. The number of sparks was increased if a piece of metal was presented to his charged body.

When Gray found that Dufay was not trespassing on his ground, but advancing knowledge, he resumed research. He concluded that if the charged person and the metal were reversed in position, sparks should come from the metal. He tried the experiment, and found that sparks could be drawn from charged insulated iron pokers, etc. Priestley states that this experiment introduced the notion of metallic conductors.

Gray and his friends noticed that when the experiments were performed in the dark, *cones* or *pencils of light* streamed from the metals. They noted separate threads of light in the cones. Thus the brush discharge was discovered in these experiments.

Gray found that a pointed rod discharged a body with gentle snaps, but a blunt rod discharged with one loud snap. From these experiments in 1734 he concluded : " in time, there may be found out a way to collect a greater quantity of the electric fire . . . which . . . seems to be of the same nature with that of thunder and lightning."

Gray died shortly after this date. The day before he died he described to the secretary of the Royal Society some experiments that convinced him that the solar system was operated by electrical forces.

A small charged iron globe was laid on resin. The experimenter held a small body over the globe by a string several inches long. It was found that the body will of itself begin to move in a circle round the globe, and constantly from west to east. With slightly different dispositions, the orbits will be ellipses of various eccentricities. Wheeler and others tried the experiments repeatedly after Gray's death, and concluded that the movement from west to east was due to the unconscious desire of the experimenter who held the string. Gray had been bemused by the planchette.

A new period of electrical research started in Germany in 1740, with the reintroduction and improvement of the machines of Guericke and Hawkesbee. Winkler used a pad instead of the hand for rubbing the glass globe, Gordon introduced a cylinder instead of the globe, and Boze added a metal conductor insulated with silk threads.

The larger electrical powers of these machines allowed new and striking experiments. Small animals were killed by sparks, colours were bleached, and spirits were fired. Small bells and wheels were operated by discharges.

In 1740 Nollet exhibited a continuous electric discharge in a partial vacuum, and described various purple-coloured streamers that appeared in the discharge vessel.

Grummert produced brilliant discharges in vacuum tubes and suggested in 1744 that they should be used " in mines and places where common fires and other lights cannot be had."

In the same year Winkler suggested that words could be spelt out in bent vacuum tubes, which could be illuminated in the dark. J. W. Ryde translates his account of the experiment: "Some exalted persons, to whom I had the honour of showing electrical experiments, were very delighted when they saw the initial letters of the most illustrious name of Augustus Rex suddenly shine out brightly in a darkened room and noticed the flood of light which instantaneously filled the glass letters." As Ryde remarks, the modern uses of discharge lamps for illumination and display had been proposed in 1744. In 1752 Watson demonstrated a tube 32 inches long which gave a steady light. This was a positive column tube of the type now used for advertising and flood-lighting.

By 1744 a large number of properties of electricity had been discovered, many of which were not utilized until the twentieth century. Electrical studies in the eighteenth century, though an expression of the philosophical attitude of the period which was rapidly becoming commercial, were not yet close enough to industrial and commercial interests to receive much direct impetus from those interests. The natural philosophers who appeared with the Renaissance were influenced by many motives. The deepest were economic and material. They applied in the sphere of intellectual work the attitude which the dominant classes of the Renaissance showed to life. This was a concern with the exploitation of the material world. The rise of the city merchants and craftsmen was accompanied by a turn of the philosophic gaze of humanity from heaven to earth, from the world of magic to the world of materials.

The pre-Renaissance ideas of magic persisted strongly into the succeeding period. In one form, they persisted as entertainment for the leisure classes. This motive was strong among the early members of the Royal Society. But a study of the early Royal Society papers shows utilitarian motives were at least as strong. It has been noticed that the first comparison of electric discharges with lightning occurred in a research inspired by utilitarian motives, an attempt to find an easier way of making phosphorus. It appeared that the manufacture of phosphorus was so profitable that the maker could quickly retire abroad with a fortune. Motives of utility are generally much more powerful than motives of entertainment; nevertheless, motives of entertainment may have considerable influence. The increase and distribution of wealth that accompanied the Renaissance increased the size of the leisured classes. A considerable part of the increased number of persons of leisure spent their time acquiring education. As the size of the leisure class increased, the proportion of intellectual members increased. What were these clever persons without work to do? They could not become monks, because society was no longer fundamentally interested in the next world. They had to busy themselves with this world. They unconsciously adapted in their entertainment the attitude of mind characteristic of the dominant trading and manufacturing classes. Playing with scientific instruments and experiments was a vicarious form of manufacturing.

By the seventeenth century the entertainments of chivalry appeared ridiculous to the keenest minds. Substitutes for Boccaccio were required. The concentration of population made hunting and the old entertainments less accessible. There was a demand for more compact forms of entertainment which could be given in rooms in cities.

Electrical phenomena were particularly suitable for this purpose. They gave flashes and cracks, and coloured lights in the dark, and could be produced by neat and clean apparatus. The electricity seemed to be made out of nothing, and appeared far more magical than the false products manufactured by the messy process of the alchemists.

E. L. Nichols has compared the public excitement raised by the discovery of the Leiden jar with the modern discoveries of X-rays and radium. He explained that the simplicity of the jar made it more striking, as nearly everyone could make experiments with it if he desired, whereas X-rays and radium cannot be demonstrated without complicated apparatus.

Another motive for the popularity of the Leiden jar was the shortage of amusements. There were no cinemas in the eighteenth century, and doubts of the propriety of public executions were beginning.

Kleist discovered the condenser accidentally. He charged a nail that had been inserted in a medicine glass. He found that he received a sharp shock when he held the glass in one hand and touched the nail with the other. The strength of the shock was increased when the glass was filled with mercury or alcohol.

The Dutch experimenters accidentally invented the jar in attempts to prevent leakages of charge. They surrounded charged bodies with glass to prevent leakage through the air. Water was placed in a glass bottle and charged by a wire. The experimenters accidentally found, like Kleist, that if the glass was held in one hand and connection with the water was made with the other, a surprising shock was experienced.

The wonders of the shocks from Leiden jars excited wide interest. Priestley describes the "sentiments of the magnanimous Mr. Boze, who with a truly philosophic heroism, worthy of the renowned Empedocles, said he wished he might die by the electric shock, that the account of his death might furnish an article for the memoirs of the French Academy of Sciences. But it is not given to every electrician to die the death of the justly envied Richman." (Richmann, who was killed in St. Petersburg by electricity he had drawn from thunder clouds.)

Everybody was eager to see and feel the effects of discharges from Leiden jars, and in many European countries numbers of persons earned a livelihood "by going about and showing" them.

The properties of the jar were strenuously investigated by William Watson and a group of fellows of the Royal Society. Watson and Bevis discovered in 1746 that if the outside of the glass bottle was covered with metal foil the strength of the discharge was increased.

"Upon shewing some Experiments to Dr. Bevis, to prove my Assertion that the Stroke was, *caeteris paribus*, to the Glass, that ingenious Gentleman has very clearly demonstrated it likewise by the following Experiment. He wrapped up two large round-bellied Phials in very thin Lead so close as to touch the Glasses everywhere except there Necks. These were filled with Water, and cork'd, with a small Wire running through each Cork into the Water."

They found that such jars could give "a most terrible shock."

This sketch will give an impression of the large number of important electrical phenomena observed by experimenters up to 1746. The accumulation of facts inspired much theorizing, most of which was very speculative. The best theorizing of the date may be illustrated by a quotation from a paper by the gifted William Watson. Here is his theory of the accumulation of electricity :

"Before I proceed further, I must beg Leave to explain what I call the Accumulation of Electricity. To put a similar Case : As we take it for granted, that there is always a determinate Quantity of Atmosphere surrounding the terraqueous Globe, we conceive, when we see the Mercury in the Barometer very low, that there is a less accumulated Column of this Atmosphere impending over us, than when we see the Mercury high. In like manner when we observe that the electrified Gun-barrel attracts or repels only very light Substances at a very small Distance, or that the Snap and Fire therefrom are scarcely perceptible ; we can conceive then a much less Quantity of electrical Atmosphere surrounding the Gun-barrel. This Power being more, or less, we call the greater or less Degree of the Accumulation of Electricity. This is only attainable to a certain Point, if you electrify ever so long ; after which, unless otherwise directed, the Dissipation thereof is general. The Phial of Water of Muschenbroek seems capable of a greater Degree of Accumulation of Electricity, than any thing we are at present acquainted with : And we see, when, by holding the Wire thereof to the Globe in Motion the Accumulation being complete, that the Surcharge runs off from the Point of the Wire, as a Brush of blue Flame."

This is first-class pre-Franklinian theorizing.

Franklin had first seen electrical experiments in 1746. He happened to receive an electrical machine from Collinson shortly afterwards, and he began experimenting with it. As he was isolated in America he had not seen any of the able European experimenters at work, so he was unable to learn any experimental technique from them. Much of the European literature containing descriptions of electrical experiments was not yet accessible to him.

Franklin had virtually retired from business, so he was able to devote his best attention to experiments with the new machine. He reported to Collinson that he was never before " engaged in any study that so totally engrossed " his attention and time. As Rutherford commented in his Franklin Bicentenary Address : " Franklin rapidly contracted the fever of the scientific discoverer," after at first having been animated, probably, by curiosity.

Within a few months Franklin discovered and rediscovered many facts, and began to theorize from them. With Hopkinson he observed " the wonderful effect of pointed bodies, both in *drawing off* and *throwing off* the electrical fire."

He found that a charged shot could be discharged by sifting fine sand on it, by breathing on it, by smoking it with burning wood, by candle-light from a distance of one foot. He supposed that " every particle of sand, moisture, or smoke, being first attracted and then repelled, carries off with it a portion of the electrical fire, but that the same still subsists in those particles, till they communicate it to something else, and that it is never really destroyed."

He observed that fire-light discharged the shot, but not sun-light. He supposed that particles from the candle took the charge away, in the same manner as sand ; and that the rarefied hot air allowed the electric fluid to pass more easily.

Schuster has remarked that if he had exposed clean zinc instead of a shot to sun-light, he would have discovered the photo-electric effect.

Franklin then states that " the electrical fire was not created by friction, but collected, being really an element diffus'd among, and attracted by other matter, particularly by water and metals."

He had observed that : " (I) A person standing on wax and rubbing the tube, and another person on wax drawing the fire, they will both of them (provided they do not stand so as to touch one another) appear to be electrized to a person standing on the floor ; that is, he will perceive a spark on approaching each of them with his knuckle. (II) But, if the persons on wax touch one another during the exciting of the tube, neither of them will appear to be electrized. (III) If they touch one another after exciting the tube, and drawing the fire as aforesaid, there will be a stronger spark between them, than was between either of them and the person on the floor. (IV) After such strong spark, neither of them discover any electricity.

" These appearances we attempt to account for thus : We suppose, as aforesaid, that electrical fire is a common element, of which every one of the three persons above mentioned has his equal share, before any operation is begun with the tube. A, who stands on wax and rubs the tube, collects the electrical fire from himself into the glass ; and his communication with the common stock being cut off by the wax, his body is not again immediately supply'd. B (who stands on wax likewise), passing his knuckle along near the tube, receives the fire which was collected by the glass from A ; and his communication with the common stock being likewise cut off, he retains the additional quantity received. To C, standing on the floor, both appear to be electrized : for he having only the middle quantity of electrical fire, receives a spark upon approaching B, who has an over quantity ; but gives one to A, who has an under quantity. If A & B approach to touch each other, the spark is stronger, because the difference between them is greater. After such touch there is no spark between either of them and C, because the electrical fire in all is reduced to the original equality. If they touch while electrizing, the equality is never destroy'd, the fire only circulating. Hence have arisen some new terms among us : we say B (and bodies like circumstanced) is electrized *positively* ; A, *negatively*. Or rather B is electrized *plus* ; A, *minus*. And we daily in our experiments electrize bodies *plus* or *minus*, as we think proper. To electrize *plus* or *minus*, no more needs to be known than this, that the parts of the tube or sphere that are rubbed, do, in the instant of the friction, attract the electrical fire, and therefore take it from the thing rubbing : the same parts immediately, as the friction upon them ceases, are disposed to give the fire they have received, to any body that has less. Thus you may circulate it, as Mr. Watson has shewn ; you may also accumulate or subtract it upon, or from any body, as you connect that body with the rubber or with the receiver, the communication with the common stock being cut off."

These passages from Franklin's first letter on his researches may be compared with the quotations from Dufay and Watson. They show that Franklin already had a clearer insigh into electricity than his predecessors. In this letter he wrote of *positive* and *negative* electricity for the first time in history. When this terminology is compared with Dufay's *vitreous* and *resinous* electricity, and Watson's more advanced view that the two sorts of electrification were due to an excess or defect of one sort of electricity, it is seen that Franklin has introduced precise, quantitative, or mathematical terminology into the subject.

This sort of achievement is a mark of the highest type of scientific mind. In addition, the argument is presented with perfect analytical clarity.

The social aspect of the experiment by which he proves the existence of positive and negative electricity is important. The experiment could not easily have been performed without the help of several intelligent persons. Franklin found these in his Junto society. Thus the existence of the Junto helped the discovery of positive and negative electricity. As Franklin had partly derived the idea of the Junto from Freemasonry, one sees a connection between this movement and electrical theory.

Franklin experimented with Leiden jars and analysed their mode of operation in terms of his quantitative electrical conceptions. He found that " The whole force of the bottle, and power of giving a shock, is in the GLASS ITSELF ; the non-electrics in contact with the two surfaces serving only to *give* and *receive* to and from the several parts of the glass ; that is, to give on one side, and take away from the other.

" This was discovered here in the following manner :

Purposing to analyze the electrified bottle, in order to find wherein its strength lay, we placed it on glass, and drew out the cork and wire, which for that purpose had been loosely put in. Then taking the bottle in one hand, and bringing a finger of the other near its mouth, a strong spark came from the water, and the shock was as violent as if the wire had remained in it, which shewed that the force did not lie in the wire.

"Then, to find if it resided in the water, being crouded into and condensed in it, as confin'd by the glass, which had been our former opinion, we electrified the bottle again, and, placing it on glass, drew out the wire and cork as before; then, taking up the bottle, we decanted all its water into an empty bottle, which likewise stood on glass; and taking up that other bottle, we expected, if the force resided in the water, to find a shock from it; but there was none. We judged then, that it must either be lost in decanting, or remain in the first bottle. The latter we found to be true, for that bottle on trial gave the shock, though filled up as it stood with fresh unelectrified water from a teapot. To find, then, whether glass had this property merely as glass, or whether the form contributed anything to it; we took a pane of sash-glass, and, laying it on the stand, placed a plate of lead on its upper surface; then electrified that plate, and bringing a finger to it, there was a spark and shock. We then took two plates of lead of equal dimensions, but less than the glass by two inches every way, and electrified the glass between them, by electrifying the uppermost lead; then separated the glass from the lead, in doing which, what little fire might be in the lead was taken out, and the glass being touched in the electrified parts with a finger, afforded only very small pricking sparks, but a great number of them might be taken from different places. Then dexterously placing it again between the leaden plates, and compleating a circle between the two surfaces, a violent shock ensued. Which demonstrated the power to reside in glass as glass, and that the non-electrics in Contact served only, like the armature of a loadstone, to unite the force of the several parts, and bring them at once to any point desired; it being the property of a non-electric, that the whole body instantly receives or gives what electrical fire is given to, or taken from, any one of its parts."

These experiments demonstrated the fundamental importance of the dielectric or insulator in electrical action, and are direct ancestors of the discovery of radio-waves. They provided the foundation for Faraday's further analysis, and proofs that the seat of electrical action is in the dielectric. From this conception Maxwell elaborated the modern theory of electricity, and deduced the probable existence of radio-waves. The Leiden jar has provided much of the inspiration for modern electrical theory, as Franklin used it to show the importance of activities in dielectrics, and Hertz first proved the existence of radio-waves with its help in 1887. The discharge of the jar is oscillatory, and the surging backwards and forwards of the electricity in the spark sends out radio-waves, as waves radiate from the place where a pebble has dropped into water.

The last paragraph of the quotation from Franklin's explanation of the action of the jar shows that he clearly understood the nature of non-electrics or electrical conductors.

The next paragraph in Franklin's letter continues :

" Upon this we made what we called an *electrical battery*, consisting of eleven panes of large sash-glass, arm'd with thin leaden plates. . . ."

Here Franklin introduced the term " electrical battery " into literature.

In 1749 he wrote that " The electrical matter consists of particles extremely subtile, since it can permeate common matter, even the densest metals, with such ease and freedom as not to receive any perceptible resistance." He considered that the experience of a shock through one's body showed that electricity might pass through, and not merely along the surfaces of substances.

He ascribed the divergence of the rays in brush discharges to the mutual repulsion of the particles of electricity.

Franklin believed electricity was of one sort only. The positive and negative states described the presence or absence of electricity. This one-fluid theory would not explain why negatively electrified bodies, i.e. bodies without electricity, repelled each other. But the necessary logical modifications are simple.

Franklin's thought and terminology is modern. Of eighteenth-century investigators Franklin could have accommodated his ideas to the modern electron theory of matter with least revision. Franklin supposed that a charged body was surrounded by an atmosphere of electrical particles. He supposed that the appearance of the corona in the dark marked the shape of this atmosphere.

" The force with which the electrified body retains its atmosphere . . . is proportioned to the surface over which the particles are placed . . . so a blunt body presented (to a charged body) cannot draw off a number of (electrical) particles at once, but a pointed one, with no greater force takes them away easily, particle by particle."

Franklin writes that he is not entirely satisfied with these explanations, but as he has nothing better to offer he does not cross them out, " for even a bad solution read, and its faults discovered, has often given rise to a good one."

He says that if there were " no other use discover'd of Electricity this however is something considerable, that it may *help to make a vain man humble* " by deceiving him into false speculations

He thinks his letter on the Leiden jar " may contain nothing new " or worth reading because the European investigators have probably discovered his results already.

" Nor is it of much importance to us, to know the manner in which nature executes her laws ; 'tis enough if we know the laws themselves, 'tis of real use to know that china left in the air unsupported will fall and break ; but *how* it comes to fall, and *why* it breaks, are matters of speculation.

" To know this power of points may possibly be of some use to mankind, though we should never be able to explain it."

He then considers the analogy between an electrified cloud and an electrified body.

" I say, if these things are so, may not the knowledge of this power of points be of use to mankind, in preserving houses, churches, ships & cont. from the stroke of lightning, by directing us to fix on the highest parts of those edifices, upright rods of iron made sharp as a needle, and gilt to prevent rusting, and from the foot of those rods a wire down one of the shrouds of a ship, and down her side till it reaches the water ? Would not these pointed rods probably draw the electrical fire silently out of a cloud before it came nigh enough to strike, and thereby secure us from that most sudden and terrible mischief ?

" To determine the question, whether the clouds that contain lightning are electrified or not, I would propose an experiment. . . ."

He describes how electricity might be drawn from an electrified cloud by a pointed rod fixed on the top of a tower or steeple. The experiment was successfully made by Dalibard in Europe. Later, Franklin himself drew electricity from the upper atmosphere with a kite.

The success of the lightning experiments established Franklin's popular fame. He had shown that one of the most mysterious phenomena, which had been associated with supernatural powers since the beginning of human intelligence, was of a material nature, and could be imitated on a small scale in the laboratory.

This was a great contribution to the emancipation of the human imagination, and, as such, of far greater value than the utility of the lightning conductor, which is not very high, as ordinary conductors are inadequate to the discharge of the huge forces released in strokes of lightning.

Franklin invented many other interesting electrical contrivances and theories. He made an electrostatic motor which would run for half an hour, driven by the discharge from two Leiden jars. He worked out theories of thunderstorms, and the origin of atmospheric electricity. But sufficient has been given to illustrate his genius.

He transformed the study of electricity into a branch of modern science when he introduced the mathematical terms *plus* and *minus*, or *positive* and *negative*.

This theoretical innovation, and the brilliant experiments from which it was deduced, secured for him the deep respect of the greatest of his intellectual contemporaries, and is the solid basis of his scientific fame.

His spectacular theories and experiments on lightning are of even more cultural than scientific interest. They brought hitherto mysterious phenomena within the range of human reason. Their contribution to modernity was their chief importance.

Incidentally, they gave Franklin a popular, semi-magical fame, which was of enormous assistance to him as a diplomat.

His accounts of his researches were exquisitely modest. He was absolutely without the jealousy common among discoverers. Finally, his scientific writings are composed in an almost incomparably lucid and spacious style.

Rutherford has remarked that the lucidity of Franklin's writings is in marked contrast to the turbidity of the writings of some of his scientific contemporaries, and it is not unreasonable to suppose that Franklin's lucidity is a fair index to the state of his conceptions of electrical actions, and the turbidity of his contemporaries to the state of theirs.

The combination of the qualities and circumstances of Franklin's electrical researches made an overwhelming impression on his generation, for just reasons.

3. LATER LIFE

The Speech of Polly Baker was published in *The Gentleman's Magazine* in London in the year in which Franklin started his electrical researches, and in the period when his intellect was at the maximum of its creative power. After his youth he rarely dispensed with an urbane style in his writings, and only on occasions when he was deeply moved. He wrote with the plainest directness, and without urbane manœuvres, in some of his dispatches from Paris to America, at the worst crises in the War of Independence. A similar plainness is seen in the style of the *Speech*.

Jefferson writes that Franklin said he wrote it to fill up space in a newspaper when news was slack. It has not been found in Franklin's own newspaper. "The Speech of Miss Polly Baker before a Court of Indicature, at Connecticut near Boston in New England ; where she was prosecuted the fifth time, for having a Bastard Child : Which influenced the Court to dispense with her Punishment, and which induced one of her Judges to marry her the next Day—by whom she had fifteen Children." This satire contains the most pointed expression of Franklin's advanced conceptions of personal relationships and morals.

By 1746, at the age of forty, Franklin had virtually retired from business. He received a considerable income from the wealth he had acquired from his holdings in various printing and other businesses. These had provided him with the means and leisure to pursue scientific researches. Thus Franklin's fortune became a little Rockefeller Foundation, whose director combined equal financial and scientific genius. His foundation also enabled him to become a politician and statesman. He vehemently agitated for the creation of militia and defences in Philadelphia, and his *Plain Truth* pamphlet contains appeals to the people to protect their "persons, fortunes, wives, and daughters" from "the wanton and unbridled rage, rapine, and lust of negroes, mulattoes, and others, the vilest and most abandoned of mankind." He writes that the rich have the means to fly, and may lodge their fortunes in distant and safe places, but "we, the middling people, the tradesmen, shopkeepers, and farmers," cannot. Therefore they must arm, in spite of their Quaker citizens' "mistaken principles of religion, joined with the love of worldly power."

In 1749 Franklin writes that he does not like negro servants and he proposes to sell the two he has at the first good opportunity. Franklin's later attitude to the negroes is shown in a letter to Condorcet written in 1774. He writes, "the negroes, who are free, live among the white people, but are generally improvident and poor. I think they are not deficient in natural understanding, but they have not the advantages of education. They make good musicians."

The electrical researches of 1746 stimulated his general scientific imagination. He mentions his discovery of the track of the north-east storms which frequently blow on the North American coast. In the same letter to Jared Eliot he comments on the strata of sea-shells on the tops of mountains and writes, "It is certainly the *wreck* of a world we live on! . . . Farther, about mountains (for ideas will string themselves like ropes of onions) . . ." Some mountains appear to be "divided by nature into pillars," as he saw "somewhere near New Haven."

In 1747 he is "satisfied we have workmen here who can make the apparatus" for electrical experiments "as well to the full as that from London; and they will do it reasonably."

He was elected a member of the Pennsylvania Assembly in 1748.

During 1750–1751 the relations between the English and the French concerning North America were strained. The colonists were anxious about the attitude of the Indians if war should start. Franklin considered this problem, and discussed what sort of population was desirable, and what laws govern the growth of populations, in his *Observations Concerning the Increase of Mankind and the Peopling of Countries.* He concluded that in America the "people must at least be doubled every twenty years," as there is "no bound to the prolific nature of plants or animals, but what is made by their crowding and interfering with each other's means of subsistence." He argues that "the labor of slaves can never be so cheap here as the labor of working men is in Britain," and that Americans purchase slaves because they cannot leave their jobs, whereas "hired men are continually leaving their masters (often in the midst of his business) and setting up for themselves.

"Slaves also perjorate the families that use them; the white children become proud, disgusted with labor, and being educated in idleness, are rendered unfit to get a living by industry."

In the same pamphlet he observes that:

"The prince that acquires new territory, if he finds it vacant, or removes the natives to give his own people room," the legislator that promotes trade and agriculture, "and the man that invents new trades, arts, or manufactures, or new improvements in husbandry, may be properly called fathers of their nation."

This pamphlet forestalled the chief conclusion of Malthus' *Essay on Population*, besides containing very suggestive contributions to other branches of social science. In it, Franklin used the notion of "natural selection," in connection with population problems; and referred to war as "a plague of heroism."

In 1753 he commented on the laziness of "the poorer English laborers" who came to America, compared with the Germans. He suggested it may be due to "the laws peculiar to England, which *compel the rich to maintain the poor*." He had observed that the Indians could not be civilized because of their former experience of the easy life of the woods, where food may be collected with very little labour, "if hunting and fishing may indeed be called labor, where game is so plenty." From this he deduces the origin of civilization. "I am apt to imagine that close societies, subsisting by labor and art, arose first not from choice but from necessity, when numbers being driven by war from their hunting grounds, and prevented by seas, or by other nations, from obtaining other hunting grounds, were crowded together into some narrow territories, which without labor could not afford them food."

He is in favour of workhouses, which, he hears, are being established in England. "I should think the poor would be more careful, and work voluntarily to lay up something for themselves against a rainy day, rather than run the risk of being obliged to work at the pleasure of others for a bare subsistence, and that too under confinement." The connection between individualist competition and biological notions of the survival of the fittest, which became prominent in the nineteenth century, are seen here in embryo.

Franklin afterwards foresaw that the high wages paid in America would tend to increase the wage-level in other countries. "The independence and prosperity of the United States of America will raise the price of wages in Europe, an advantage of which I believe no one has yet spoken." He contended that the principle of reducing wages in order to increase exports was mistaken. Exports should be increased by decreasing the price of goods, not by decreasing the wages of the workmen who made them.

"The price of labor in the arts, and even in agriculture, is wonderfully diminishing by the perfection of the machinery employed in them."

He explains that improved machinery and "judicious subdivision of labor" will reduce the costs of production, and hence the price. These principles do not have any logically necessary connection with low wages. High wages attract the best workmen, who spoil fewer tools and material, work faster, and produce the best goods. "The perfection of machinery in all the arts is owing, in a great degree, to the workmen." They make the inventions and improvements.

Low wages are not "the real cause of the advantages of commerce between one nation and another"; but are "one of the greatest evils of political communities."

"Wages in England are higher than in other parts of Europe, owing to more efficient machinery and labour organization. In America wages are still higher, owing to the special circumstances of high demand for labour in a new country whose population and agriculture are expanding rapidly. The expansion of the American market will increase the demand for goods, and hence increase wages, in Europe. Emigration to America will decrease the number of workmen in Europe, and increase the wages of the remainder through competition."

Franklin discusses the argument that improved technique will not necessarily increase wages, because the very small number of "proprietors and capitalists" will keep wages as low as possible, owing to the operation of forces "inherent in the constitutions of European states." He suggests that "the causes, which tend continually to accumulate and concentrate landed property and wealth in a few hands" may be diminished by political action inspired by the success of the Americans in securing independence and liberty. "The remains of the feudal system might be abolished," the mode of taxation changed, and commercial regulations amended.

The problems of defence against the French and Indians were the occasion for an assembly of commissioners from the various colonies at Albany. Franklin represented Pennsylvania. The question of union had been ardently discussed in the colonies, so Franklin, without instructions from his assembly, presented to the commission a plan containing *Short Hints towards a Scheme for Uniting the Northern Colonies.* Other unauthorized plans were also submitted, but Franklin's was approved.

The scheme consisted of a governor-general, a soldier appointed and paid by the King, and a council containing delegates from the assemblies. The council was to propose acts, which would be carried out, or vetoed, by the governor-general. Its funds were to be drawn from an excise duty on strong liquors.

Franklin said that the assemblies found the scheme gave too much power to the crown, and the British Government thought it too democratic.

The scheme was the first plan of union of the American colonies which received official discussion. It contained no suggestion of American independence.

The colonists considered the plan gave the crown half the power, whereas " in the British constitution, the crown is supposed to possess but one third, the lords having their share."

As the choice of the commissioners " was not immediately popular, they would be generally men of good abilities for business, and men of reputation for integrity ; and that forty-eight such men might be a number sufficient."

Later in 1754 Franklin was asked by Governor Shirley of Pennsylvania to report secretly on a suggestion of the British to nominate members of the proposed grand council and to tax the colonies. John Adams said that " this sagacious gentleman and distinguished patriot, to his lasting honor, sent the governor an answer in writing " which powerfully opposed the suggestion of taxing the colonists " by act of Parliament, where they have no representation," and " excluding the people from all share in the choice of the grand council." This answer was published in England twelve years later.

The disputes on taxation became serious by 1757, so Franklin was sent by the Pennsylvania Assembly as their Agent to London to negotiate their disputes with the Penn family, the proprietors of Pennsylvania, and the British Government.

While waiting to embark at New York, he wrote to a friend his reflections on the production of cold by evaporation, of which he had just heard from Professor Simson of Glasgow. He has supposed electricity to be a fluid, and considers heat is also a fluid. Heat expansion is due to the filling of the pores of bodies with the fluid. Melting and evaporation are due to the forcing apart of the constituent particles ; " a damp moist air shall make a man more sensible of cold, or chill him more, than a dry air that is colder, because a moist air is fitter to receive and conduct away the heat of his body."

The fluid fire is attracted by plants in their growth and is consolidated with the other materials of which they are formed. When bodies burn, the fluid fire and air escape again. "I imagine that animal heat arises by or from a kind of fermentation in the juices of the body, in the same manner as heat arises in the liquors preparing for distillation, wherein there is a separation of the spirituous from the watery and earthy parts. And it is remarkable that the liquor in a distiller's vat, when in its highest and best state of fermentation, as I have been informed, has the same degree of heat with the human body—that is, about 94 or 96.

"Thus, as by a constant supply of fuel in a chimney you keep a room warm, so by a constant supply of food in the stomach, you keep a warm body." Clothing does not give a man warmth, but prevents the dissipation of his natural heat. He supposes that mixtures of snow and salt cool because they are better conductors than the constituents. This would explain why the snow and salt appear to dissolve into water, at the low temperature, without freezing.

In another letter he refers to the ancient knowledge in the East of cooling by evaporation. Water flasks were cooled by wrapping in wet woollen cloths. Water in unglazed pots was cooled by evaporation through the pores. The evaporation of sweat therefore explained how the human body kept cool in hot weather, and why the temperature of a live body kept below high summer temperatures, whereas a corpse acquired them. Evaporation explained why reapers in Pennsylvania were liable to drop dead if they did not drink freely. If they did not drink freely, they did not sweat, and so could not be cooled to a healthy temperature. Plants probably remain cool in the sunshine by evaporation. Franklin concludes by suggesting that painful inflammations would be cooled better by rags soaked in spirit than in water, because the spirit evaporates more quickly.

Soon after Franklin arrived in England he sought his relatives and ancestors, showing the characteristic American interest in genealogy.

He took rooms in the house of Mrs. Stevenson of Craven Street, by the Strand. She had a charming daughter, to whom he enjoyed giving lessons in, and writing letters on, science and learning. In one of these, which has already been quoted, he described experiments by which he had compared the power of different coloured bodies to absorb heat radiation from the sun. In another, he summarized the utility of insects to man, and concluded his remarks :

" The knowledge of nature may be ornamental, and it may be useful ; but if, to attain an eminence in that, we neglect the knowledge and practice of essential duties, we deserve reprehension. For there is no rank in natural knowledge of equal dignity and importance with that of being a good husband or wife, a good neighbour or friend, a good subject or citizen—that is, in short, a good Christian."

The end of the war between England and France was approaching in 1760. Some in England were in favour of leaving Canada to the French, and taking territory in the West Indies. Franklin combated this view in a pamphlet. He discussed the future of North America, and the need for controlling the unsettled lands of the Mississippi, in the interests of England. The English were jealous of the rise of manufactures in America, because it would damage their export trade. Franklin wrote : " Manufactures are founded on poverty. It is the multitude of poor without land in a country, and who must work for others at low wages or starve, that enables undertakers to carry on a manufacture, and afford it cheap enough to prevent the importation of the same kind from abroad, and to bear the expense of its own exportation.

" But no man, who can have a piece of land of his own, sufficient by his labor to subsist his family in plenty, is poor enough to be a manufacturer, and work for a master. Hence, while there is land enough in America for our people, there can never be manufactures to any amount or value." It was therefore to the interest of England to retain the unsettled lands of Canada and the West.

He explains that the establishment of industrialism in a sparsely populated country is complicated and cannot be introduced in parts, owing to the subdivision of labour. A complete set of skilled workmen cannot be persuaded to leave their own country. Countries rarely lose established industries, except by bad police oppression or religious persecution. " They sometimes start up in a new place like exotic plants," but do not pay " until these new sects become the refuge of the manufacturers driven from the old ones." The presence of manufacturing in any place is not due to soil, climate, or freedom from taxes.

As Agent for Pennsylvania Franklin had to negotiate with the British Government concerning the numerous disputes between the Proprietaries, who had been presented with the land of the province by Charles the Second, and the inhabitants represented by the Assembly. His experiences inclined him to think in 1764 that " the cause of these miserable contentions is not to be sought for merely in the depravity and selfishness of human minds." He suspected " the cause is radical, interwoven in the constitution, and so become the very nature, of proprietary governments ; and will therefore produce its effects, as long as such governments contnue. And, as some physicians say, every animal body brings into the world among its original stamina the seeds of that disease that shall finally produce its dissolution ; so the political body of a proprietary government contains those convulsive principles that will at length destroy it."

In another discussion of proprietary troubles he remarks : " Such is the imperfection of our language, and perhaps of all other languages, that, notwithstanding we are furnished with dictionaries innumerable, we cannot precisely know the import of words, unless we know of what party the man is that uses them."

Franklin returned to America in 1762. In the same year his son William was appointed Governor of New Jersey, at the age of thirty-one years. William Franklin had been born in 1731, the year after Franklin was married, but his mother was not Franklin's wife. He was carefully educated and pushed by his father. Franklin said the appointment was not solicited, and opponents of the British Ministry suggested it was an indirect bribe to embarrass him in his work as Colonial Agent. Thomas Penn, one of the Proprietaries of Pennsylvania, wrote : " I am told you will find Mr. Franklin more tractable, and I believe we shall, in matters of prerogative ; as his son must obey instructions, and what he is ordered to do his father cannot well oppose in Pennsylvania." William Franklin became an ardent Royalist. He resolutely resisted the insurgents in the War of Independence, and retired to England with a pension and reparation from the British Government. He died in 1813 at the age of eighty-two years. His son William Temple Franklin was also illegitimate. Franklin took the youth with him to Paris, to act as private secretary, and afterwards repeatedly solicited Congress to give him a place in the diplomatic service. Congress evaded these solicitations. The grandson was of mediocre ability. He was unhappy in America, after living with Franklin for many years in Paris, and finally returned to his father in England, and died at Paris in 1823.

The great wars by which England captured the colonies of France in Canada and India were ended in 1763. The British

Government had difficulty in finding the money to pay for the wars, so they decided to tax the American colonies. They considered the Americans owed their protection against France chiefly to the British navy and army, and therefore the Americans should contribute to their cost. The size of the contributions was to be decided by the House of Commons, and not by the colonial assemblies. An act was passed, by which all business and legal transactions in America were declared invalid without stamps. These could be purchased with gold or silver money only. The colonists violently opposed the act, as they disliked paying increased taxes, had real difficulty in finding gold to send to England, owing to the drain on it to pay for imports from England, and disputed the right of the House of Commons to tax them when unrepresented. They contended that taxation without representation was contrary to the principle of British political liberty. At the beginning of this agitation Franklin was again sent to England to protest against the stamp proposals, and to petition for the recognition of Pennsylvania as a crown colony. Nevertheless, the Stamp Act was passed, and the petition failed.

The Stamp Act excited riots in America, and even demonstrations against Franklin's relatives. His wife describes how she prepared to protect her house with firearms against demonstrators.

Franklin was consulted in London by the British authorities on the causes of the uproar. His brilliant advocacy of the colonies' case when examined before members of the House of Commons and explanations to other important persons, weakened the influence of the British Ministry, and helped to force it to resign. The new ministry repealed the act in 1766.

In the summer of 1766 Franklin visited the continent of Europe with Sir John Pringle, the physician and scientist. They visited Paris in 1767, and Franklin became personally acquainted with many eminent Frenchmen. This contact proved of great importance later in his career. Pringle was elected President of the Royal Society in 1772. When the struggle between the British Ministry and the colonies became acute, George III, in his annoyance with Franklin and the Americans, ordered that the lightning conductors on Kew Palace should have blunt knobs instead of sharp points. Franklin, the inventor of conductors, had directed that the points should be sharp, so that an overcharge of electricity might be dispersed silently and without explosion. The question of blunt and sharp conductors became a court question, the courtiers siding with the King, and their opponents with Franklin. The King asked Sir John Pringle to take his side, and give him an opinion in favour of the knobs. To which Pringle replied by hinting that the laws of nature were not changeable at Royal pleasure. It was then intimated to him by the King's authority that a President of the Royal Society entertaining such an opinion ought to resign, and he resigned accordingly.

This incident inspired the epigram :

While you, great George, for safety hunt,
And sharp conductors change for blunt,
  The nation's out of joint.
Franklin a wiser course pursues,
And all your thunder fearless views,
  By keeping to the point.

During the discussions concerning the right to tax Americans not represented in the House of Commons, the supporters of taxation argued that many Englishmen who were not represented were nevertheless taxed. Franklin commented : "Copy-holds and lease-holds are supposed to be represented in the original landlord of whom they are held. Thus all the land in England is in fact represented. . . . As to those who have no landed property in a county, the allowing them to vote for legislators is an impropriety. They are transient inhabitants, and not so connected with the welfare of the state, which they may quit when they please, as to qualify them properly for such privilege."

In 1767 Franklin wrote to Lord Kames : "Upon the whole, I have lived so great a part of my life in Britain, and have formed so many friendships in it, that I love it, and sincerely wish it prosperity ; and therefore wish to see that union, on which alone I think it can be secured and established. As to America, the advantages of such a union to her are not so apparent. She may suffer at present under the arbitrary power of this country ; she may suffer for a while in a separation from it ; but these are temporary evils which she will outgrow. Scotland and Ireland are differently circumstanced. Confined by the sea, they can scarcely increase in numbers, wealth, and strength, so as to overbalance England. But America, an immense territory, favoured by nature with all advantages of climate, soils, great navigable rivers, lakes, &c., must become a great country, populous and mighty ; and will, in less time than is generally conceived, be able to shake off any shackles that may be imposed on her, and perhaps place them on the imposers. In the meantime every act of oppression will sour their tempers, lessen greatly, if not annihilate, the profits of your commerce with them, and hasten their final revolt ; for the seeds of liberty are universally found there, and nothing can eradicate them. And yet there remains among that people so much respect, veneration, and affection for Britain, that, if cultivated prudently, with a kind usage and tenderness for their privileges, they might be easily governed still for ages, without force or any considerable expense. But I do not see here a sufficient quantity of the wisdom that is necessary to produce such a conduct, and I lament the want of it."

In 1767 Franklin wrote a pamphlet against the British Government's embargo on the exportation of corn. He supported the farmers' complaint that the price of corn was reduced. " You say poor laborers cannot afford to buy bread at a high price unless they had higher wages." " I am for doing good for the poor ; but I differ in opinion about the means. I think the best way of doing good to the poor is, not making them easy *in* poverty, but leading or driving them *out* of it." " More will be done for their happiness by inuring them to provide for themselves, than could be done by dividing all your estates among them."

In 1767 he wrote against the impressing of seamen ; " there being no slavery worse than that sailors are subjected to." Franklin contended that conscription should apply to all citizens, or none. If volunteers could not be attracted, " the end might be answered by giving higher wages."

In 1768 he wrote to his son complaining that an editor of an English paper, " one Jones, has drawn the teeth and pared the nails of my paper, so that it can neither scratch nor bite. It seems only to paw and mumble. . . . I am told there has been a talk of getting me appointed undersecretary to Lord Hillsborough ; but with little likelihood, as it is a settled point there that I am too much of an American."

The Parliamentary changes were accompanied by an election. " Great complaints are made that the natural interest of country gentlemen in their neighbouring boroughs is overborne by the moneyed interests of the new people, who have got sudden fortunes in the Indies, or as contractors. *Four thousand pounds* is now the *market price* for a borough. In short, this whole venale nation is now at market, will be sold for about two millions, and might be bought out of the hands of the present bidders (if he would offer half a million more) by the very Devil himself.

"The crown has *two millions a year in places and pensions to dispose of*, and it is well worth while to engage in such a seven years' lottery, though all that have tickets should not get prizes."

Franklin witnessed the scenes of Wilkes' election for Middlesex. The mob smashed the windows of all who refused to illuminate their houses in Wilkes' honour, " for an outlaw and an exile, of bad personal character, not worth a farthing." He writes that " property and even life is little more secure in London than on the disturbed American frontiers." The condition of London weakened confidence in the American argument for more democratic government, and direct rule of the colonies under the crown, without the control of the House of Commons. " Mobs patrolling the streets at noonday, some knocking all down that will not roar for Wilkes and liberty ; courts of justice afraid to give judgment against him ; coal-heavers and porters pulling down the houses of coal merchants that refuse to give them more wages ; sailors unrigging all the outward-bound ships, and suffering none to sail till merchants agree to raise their pay ; watermen destroying private boats and threatening bridges ; soldiers firing among the mobs and killing men, women, and children, which seems only to have produced a universal sullenness, that looks like a great black cloud coming on, ready to burst in a general tempest."

Franklin wrote many years later, in 1781, that " if George the Third had had a bad private character, and John Wilkes a good one, the latter might have turned the former out of his kingdom."

During the tense Anglo-American disputes, and the Wilkes excitements, Franklin made some experiments in hydrodynamics. He and Pringle had observed in Holland that canal boats sailed less quickly in shallow than in deep water. The phenomenon was well known to the watermen, who knew that a dry summer would slow down canal traffic. Not having found any references to the effect " in our philosophical books," Franklin constructed a hydrodynamical model of a canal, " fourteen feet long, six inches wide, and six inches deep, in the clear, filled with water within half an inch of the edge." The model boat was " six inches long, two inches and a quarter wide, and one inch and a quarter deep.

When swimming it drew one inch water. To give motion to the boat I fixed one end of a long silk thread to its bow, just even with the water's edge, the other end passed over a well-made brass pulley of about an inch diameter, turning freely on a small axis; and a shilling was the weight. Then placing the boat at one end of the trough, the weight would draw it through the water to the other."

Franklin measured the time taken by the boat to sail from end to end with water 1½, 2, and 4½ inches deep. The times were respectively 101, 89, and 79 units. He concluded that if "four men or horses would draw a boat in deep water four leagues in four hours, it would require five to draw the same boat in the same time as far in shallow water. . . . Whether this difference is of consequence enough to justify a greater expense in deepening canals, is a matter of calculation, which our ingenious engineers in that way will readily determine."

At the same time he advised a friend to learn to swim by "choosing a place where the water deepens gradually, walk coolly into it till it is up to your breast, then turn round, your face to the shore, and throw an egg into the water between you and the shore. It will sink to the bottom, and be easily seen there. . . ." Franklin gives an elaborate account of how the learner should retrieve the egg, so that he learns to swim during the retrieval.

He describes how he used kites to draw him through the water when he was a boy, and suggests they might be used to assist swimmers trying to cross the English channel from Dover to Calais. He adds that "the packet-boat, however, is still preferable."

In one of the many articles written in 1769 on the Anglo-American dispute, Franklin discusses "the excellency of the invention of colony government, by separate, independent legislatures. By this means, the remotest parts of a great empire may be as well governed as the center; mis-rule, oppressions of proconsuls, and discontents and rebellions thence arising, prevented. By this means the power of a king may be extended without inconvenience over territories of any dimensions, how great soever. America was thus happily governed in all its different and remote settlements, by the crown and their own assemblies, till the new politics took place of governing it by one Parliament, which have not succeeded and never will."

In another pamphlet he remarks: "ought the rich in Britain, who have made such numbers of poor by engrossing all the small divisions of land, and who keep the laborers and working people poor by limiting their wages,—ought those gentry to complain of the burden of maintaining the poor ?"

He visited a large coal mine near Whitehaven in Cumberland during the summer. He noticed the impressions of fossil ferns on coal in seams deep under the sea, and wrote to the French philosopher Dubourg : "I am persuaded, as well as you, that the sea coal has a vegetable origin, and that it has been formed near the surface of the earth ; but, as preceding convulsions of nature had served to bring it very deep in many places, and covered it with many different strata, we are indebted to subsequent convulsions for having brought within our view the extremities of its remains, so as to lead us to penetrate the earth in search of it."

Franklin continues to repeat during 1770 his arguments concerning the encroachments of the Lords and Commons on the prerogative of the sovereign. "By our constitutions he is, with his plantation parliaments, the sole legislator of his American subjects." "Let us, therefore, hold fast our loyalty to our King, who has the best disposition towards us and has a family interest in our prosperity ; as that steady loyalty is the most probable means of securing us from the arbitrary power of a corrupt Parliament."

Franklin was deeply interested in the introduction of new industries, such as silk-worm cultivation, into America. In 1771 he quotes Ogilby's description of silk-worm cultivation in China. "They prune their mulberry-trees once a year, as we do our vines in Europe, and suffer them not to grow up into high trees, because through long experience they have learned that the leaves of the smallest and youngest trees make the best silk, and know thereby how to distinguish the first spinning of the threads from the second, viz. : the first is that which comes from the young leaves, that are gathered in March, with which they feed their silkworms ; and the second is of the old summer leaves. And it is only the change of food, as to the young and old leaves, which makes the difference in the silk. The prices of the first and second spinning differ among the Chineses. The best silk is that of March, the coarsest of June, yet both in one year."

Franklin comments : "I have copied this passage to show that in Chekiang they keep the mulberry-trees low ; but I suppose the reason to be the greater facility of gathering the leaves."

There are other examples in Franklin's writings of his notice of the biological and other aspects of nutrition. He had read reviews of Lind's book on the diseases of seamen. In 1757 Lind published accounts of simple scientifically controlled experiments on the administration of plant products to seamen suffering from scurvy. His experiments showed that dried spinach was useless, as it lost during drying " something contained in the natural juices of the plant " which " no moisture whatever could replace." This is the earliest scientific evidence for the existence of vitamins.

Franklin introduced rhubarb cultivation into America.

In 1771 he corresponded with T. Percival, the chief founder of the Manchester Literary and Philosophical Society. He suggested that a drop of rain may often grow while falling, " attracting to itself such (drops) as do not lie directly in its course by its different state with regard either to common or electric fire."

Differences of common fire, or heat, cause coagulation, as the moisture in warm air coagulates with the walls of a glass containing cold water.

" An electrified body, left in a room for some time, will be more covered with dust than other bodies in the same room not electrified, which dust seems to be attracted from the circumambient air."

Franklin suggests that raindrops may coagulate through a similar electrical process of precipitation, as " we know that the drops of rain are often electrified " ; and the falling of hail on hot days shows that great differences of temperature exist in the atmosphere. Hence differences in temperature and electrical charge may explain the growth of raindrops.

In November 1771 he advises his friend Mrs. Hewson (formerly Mary Stevenson, whom he had hoped would have married his son) how to manage her baby. " Pray let him have every thing he likes. I think it of great consequence while the features are forming ; it gives them a pleasant air, and, that being once become natural and fixed by habit, the face is ever after the handsomer for it, and on that much of a person's good fortune and success in life may depend. Had I been crossed as much in my infant likings and inclinations as you know I have been of late years, I should have been, I was going to say, not near so handsome, but as the vanity of that expression would offend other folks' vanity, I change it out of regard to them and say a great deal more homely."

Franklin made a tour in Ireland and Scotland in 1771. He was appalled by the contrast between the opulence of the wealthy and the wretchedness of the poor. He writes with reference to the condition of the bulk of the population: "Had I never been in the American colonies, where every man is a freeholder, has a vote in public affairs, lives in a tidy warm house, has plenty of good food, but were to form my judgment of civil society by what I have lately seen, I should never advise a nation of savages to admit of civilization; for I assure you that, in the possession and enjoyment of the various comforts of life, compared to these people, every Indian is a gentleman."

In 1772 Franklin visited various English towns and called on Joseph Priestley at Leeds. On July 1st Priestley wrote: "I presume that by this time you are arrived in London, and I am willing to take the first opportunity of informing you that I had never been so busy, or so successful in making experiments, as since I had the pleasure of seeing you at Leeds." Priestley then describes his discovery that sprigs of mint could restore the quality of air rendered noxious by breathing, and other experiments which preceded his discovery of oxygen.

On August 19th, 1772, Franklin described to his son how he was cultivated by the diplomatic corps in London, and treated as an unofficial member, and that his company was so much desired that he rarely dined at home in winter, Learned and ingenious foreigners make a point of visiting him, "for my reputation is still higher abroad than here."

Three days later he was elected one of the eight foreign members of the French Academy of Sciences.

In September he describes his system of *moral or prudential algebra* to Priestley. "Divide half a sheet of paper by a line into two columns; writing over the one *pro* and over the other *con*; then during three or four days' consideration, I put down under the different heads short hints of the different motives, that at different times occur to me, *for* or *against* the measure. When I have thus got them all together in one view, I endeavour to estimate their respective weights; and, where I find two (one on each side) that seem equal, I strike them both out. If I find a reason *pro* equal to some two reasons *con*, I strike out the three. If I judge some two reasons *con*, equal to some three reasons *pro*, I strike out the five; and thus proceeding I find at length where the balance lies; and if, after a day or two of further consideration, nothing new that is of importance occurs on either side, I come to a determination accordingly."

He remembers that the weight of reasons cannot be determined with mathematical exactitude, but he finds the comparative study of the collected reasons improves his judgment and restrains rashness.

In December 1772, he observes in a letter: "The people seldom continue long in the wrong, when it is nobody's interest to mislead them."

Franklin performed tolerably well on several musical instruments. He had noticed the sweet tone emitted by rubbing the fingers on wet glasses. He devised a harmonica consisting of a series of glass dials on which melodies could be played with clean, damp fingers. These musical interests led him to consider the explanation of the popularity of Scottish and other folk airs. He was an anti-modernist, and criticized advanced contemporary music as cacophonous.

In 1772 the President of the Board of Trade, Lord Hillsborough, drew up a report on the petition of Walpole, Franklin, Sargent, and Wharton for permission to make a settlement on the Ohio River. He opposed the petition, but the arguments and influence of Franklin and his friends caused the permission to be granted. Hillsborough was headstrong, and resigned in anger when his advice was not accepted. In his report it is stated that "The great object of colonizing upon the continent of North America has been to improve and extend the commerce, navigation, and manufactures of this kingdom (Great Britain), upon which its strength and security depend." He quotes the commander-in-chief of the British forces in America: "Let the savages enjoy their deserts in peace."

Hillsborough and the anti-American party did not conceive colonization as the creation of new countries and nations in hitherto savage countries, and could not appreciate Franklin's conception of an empire consisting of self-governing dominions under one crown.

In 1773 Franklin wrote to Dubourg that "as to the magnetism which seems produced by electricity, my real opinion is that these two powers of nature have no affinity with each other, and that the apparent production of magnetism is purely accidental." He considered magnetism due to the movements of a magnetic fluid. In another letter to the same philosopher concerning the nature of death he comments on the preservation of food and of living animals, and remarks that the invention of processes for doing this would be valuable for transporting "those delicate plants which are unable to sustain the inclemency of the weather at sea." He recalls that he has "seen an instance of common flies preserved." "They had been drowned in Madeira wine, apparently about the time when it was bottled in Virginia to be sent hither (London). At the opening of one of the bottles at the house of a friend where I then was three drowned flies fell into the first glass that was filled. Having heard it remarked that drowned flies were capable of being revived by the rays of the sun, I proposed making the experiment upon these. They were, therefore, exposed to the sun upon a sieve which had been employed to strain them out of the wine. In less than three hours two of them began by degrees to recover life. They commenced by some convulsive motions of the thighs, and at length they raised themselves upon their legs, wiped their eyes with their forefeet, beat and brushed their wings with their hind feet, and soon after began to fly, finding themselves in Old England, without knowing how they came thither.

"I wish it were possible, from this instance, to invent a method of embalming drowned persons in such a manner that they may be recalled to life at any period, however distant; for having a very ardent desire to see and observe the state of America a hundred years hence, I should prefer to any ordinary death the being immersed in a cask of Madeira wine with a few friends until that time, to be then recalled to life by the solar warmth of my dear country! But since in all probability we live in an age too early and too near the infancy of science to hope to see such an art brought in our time to its perfection, I must for the present content myself with the treat which you are so kind as to promise me of the resurrection of a fowl or a turkey-cock."

Franklin had been in London as Agent of Pennsylvania for seventeen years. Massachusetts and other colonies had also appointed him agent. He was now sixty-seven years old, and thought of retiring. A young Bostonian, named Arthur Lee, who had been educated at Eton, was appointed Agent-designate for Massachusetts. Lee disagreed with Franklin in temperament and opinions, and did not disguise his anxiety for Franklin's return. Franklin refers to this in a letter to a Boston clergyman.

To another Boston clergyman he remarks: "Providence seems by every means intent on making us a great people." While he was noting the growing strength of America, he noted the increasing obstinacy of the King.

In 1773 he writes to his son: "Between you and me, the late measures have been, I suspect, very much the king's own, and he has in some cases a great share of what his friends call *firmness*."

Franklin wrote to Dr. Percival concerning the high death-rate in Manchester. He considered that the manufacturing life appeared to be unwholesome, owing to lack of housing space, poverty, and drinking. " Farmers who manufacture in their own families what they have occasion for and no more, are perhaps the happiest people and the healthiest."

He does not believe that colds are due to damp clothes, moist or fresh air, but over-eating in proportion to exercise. He compared the loss of weight by perspiration when a man is naked and when he is clothed. A young physician was engaged to sit naked for one hour. His perspiration loss was compared with the loss when clothed, and was found to be almost doubled. Franklin concluded that the notion that common colds are due to stopping pores or obstructing perspiration is ill founded.

Franklin astonished his friends in 1773 by calming the waves on Derwentwater, in the British Lake District, with oil. The report of this experiment raised much interest, so Franklin wrote an account of the subject for the Royal Society. He writes : " I had, when a youth, read and smiled at Pliny's account of a practice among the seamen of his time, to still the waves in a storm by pouring oil into the sea . . . it has been of late too much the mode to slight the learning of the ancients. The learned, too, are apt to slight too much the knowledge of the vulgar. The cooling by evaporation was long an instance of the latter. The art of smoothing the waves by oil is an instance of both.

" In 1757, being at sea in a fleet of ninety-six sail bound against Louisberg, I observed the wakes of two of the ships to be remarkably smooth, while all the others were ruffled by the wind, which blew fresh. Being puzzled with the differing appearance, I at last pointed it out to our captain, and asked him the meaning of it. ' The cooks,' said he, ' have, I suppose, been just emptying their greasy water through the scuppers, which had greased the sides of those ships a little.' And this answer he gave me with an air of some little contempt, as to a person ignorant of what everybody else knew. In my own mind I at first slighted his solution, though I was not able to think of another ; but recollecting what I had formerly read in Pliny, I resolved to make some experiments of the effect of oil on water, when I should have opportunity." He was at sea again in 1762, and noticed " the wonderful quietness of oil on agitated water in the swinging glass lamp made to hang up in the cabin. This I was continually looking at and considering as an appearance to me inexplicable. An old sea captain, then a passenger with me, thought little of it, supposing it an effect of the same kind with that of oil put on water to smooth it, which he said was a practice of the Bermudians when they would strike fish, which they could not see if the surface of the water was ruffled by the wind. This practice I had never before heard of, and was obliged to him for the information; though I thought him mistaken as to the sameness of the experiment, the operations being different as well as the effects. In one case the water is smooth till the oil is put on, and then becomes agitated. In the other it is agitated before the oil is applied, and then becomes smooth."

The sea captain also told him that the fishermen of Lisbon reduced the surf on the bar of the river by pouring oil on the water. A person who had often been in the Mediterranean informed him "that the divers there, who, when under water in their business, need light, which the curling of the surface interrupts by the refractions of so many little waves, let a small quantity of oil now and then out of their mouths, which rising to the surface smooths it, and permits the light to come down to them. All these informations I at times revolved in my mind, and wondered to find no mention of them in our books of experimental philosophy.

"At length being at Clapham (London), where there is, on the common, a large pond, which I observed one day to be very rough with the wind, I fetched out a cruet of oil, and dropped a little of it on the water. I saw it spread itself with surprising swiftness upon the surface; but the effect of smoothing the waves was not produced; for I had applied it first on the leeward side of the pond, where the waves were greatest; and the wind drove my oil back upon the shore. I then went to the windward side where they began to form; and there the oil, though not more than a teaspoonful, produced an instant calm over a space several yards square, which spread amazingly, and extended itself gradually till it reached the lee side, making all that quarter of the pond, perhaps half an acre, as smooth as a looking-glass.

"After this I contrived to take with me, whenever I went into the country, a little oil in the upper hollow joint of my bamboo cane, with which I might repeat the experiment as opportunity should offer, and I found it constantly to succeed.

"In these experiments, one circumstance struck me with particular surprise. This was the sudden, wide, and forcible spreading of a drop of oil on the face of the water, which I do not know that anybody has hitherto considered. If a drop of oil is put on a highly polished marble table, or on a looking-glass that lies horizontally, the drop remains in its place, spreading very little. But, when put on water, it spreads instantly many feet round, becoming so thin as to produce the prismatic colours, for a considerable space, and beyond them so much thinner as to be invisible, except in its effect of smoothing the waves at a much greater distance. It seems as if a mutual repulsion between its particles took place as soon as it touched the water, and a repulsion so strong as to act on other bodies swimming on the surface, as straw, leaves, chips, etc., forcing them to recede every way from the drop, as from a centre, leaving a large clear space. The quantity of this force, and the distance to which it will operate, I have not yet ascertained ; but I think it is a curious inquiry, and I wish to understand whence it arises.

"In our journey to the north . . . we visited the celebrated Mr. Smeaton, near Leeds. Being about to show him the smoothing experiment on a little pond near his house, an ingenious pupil of his, Mr. Jessop, then present, told us of an odd appearance on that pond which had lately occurred to him. He was about to clean a little cup in which he kept oil, and he threw upon the water some flies that had been drowned in the oil. These flies presently began to move, and turned round on the water very rapidly, as if they were vigorously alive, though on examination he found they were not so. I immediately concluded that the motion was occasioned by the power of the repulsion above mentioned, and that the oil, issuing gradually from the spongy body of the fly, continued the motion. He found some more flies drowned in oil, with which the experiment was repeated before us. To show that it was not any effect of life recovered by the flies, I imitated it by bits of oiled chips and paper, cut in the form of a comma, of the size of a common fly ; when the stream of repelling particles issuing from the point made the comma turn round the contrary way. This is not a chamber experiment ; for it cannot be well repeated in a bowl or dish of water on a table. A considerable surface of water is necessary to give room for the expansion of a small quantity of oil. In a dish of water, if the smallest drop of oil be let fall in the middle, the whole surface is presently covered with a thin greasy film [and when the film] has reached the sides of the dish, no more will issue from the drop, but it remains in the form of oil ; the sides of the dish putting a stop to its dissipation by prohibiting the farther expansion of the film."

Franklin then discusses the mode of the calming action of the oil.

" There seems to be no natural repulsion between water and air, such as to keep them from coming into contact with each other. Hence we find a quantity of air in water ; and if we extract it by means of the air pump, the same water again exposed to the air will soon imbibe an equal quantity.

" Therefore air in motion, which is wind, in passing over the smooth surface of water, may rub, as it were, upon that surface, and raise it into wrinkles, which, if the wind continues, are the elements of future waves.

" The small first-raised waves, being continually acted upon by the wind, are, though the wind does not increase in strength, continually increased in magnitude, rising higher, and extending their bases, so as to include a vast mass of water in each wave, which in its motion acts with great violence.

" But if there is a mutual repulsion between the particles of oil, and no attraction between oil and water, oil dropped on water will not be held together by adhesion to the spot whereon it falls ; it will not be imbibed by the water ; it will be at liberty to expand itself ; and it will spread on a surface that, besides being smooth to the most perfect degree of polish, prevents, perhaps by repelling the oil, all immediate contact, keeping it at a minute distance from itself ; and the expansion will continue till the mutual repulsion between the particles of the oil is weakened and reduced to nothing by their distance.

" Now I imagine that the wind, blowing over water thus covered with a film of oil, cannot easily *catch* upon it, so as to raise the first wrinkles, but slides over it, and leaves it smooth as it finds it.

" The wind thus prevented from raising the first wrinkles, that I call the elements of waves, cannot produce waves, which are to be made by continually acting upon, and enlarging those elements," and thus the water is calmed.

" We might suppress the waves in any required place, if we could come at the windward place where they take their rise. This in the ocean can seldom if ever be done. But perhaps something may be done on particular occasions, to moderate the violence of the waves when we are in the midst of them, and prevent their breaking where that would be inconvenient.

"For, when the wind blows fresh, there are continually rising on the back of every great wave a number of small ones, which roughen its surface, and give the wind hold, as it were, to push it with greater force. This hold is diminished, by preventing the generation of those smaller ones. And possibly too, when a wave's surface is oiled, the wind in passing over it may rather in some degree press it down, and contribute to prevent its rising again, instead of promoting it."

Franklin, Banks, Solander, Carnoc, and Blagden with Captain Bentinck experimented off the shore near Portsmouth in a blustering wind, to see whether the surf could be reduced by pouring oil on the sea from a large stone bottle. The experiment failed, for the surf on the shore was not sensibly reduced. Franklin suggested they had not used sufficient oil, and had not started pouring the oil sufficiently far from the shore. He thanked his colleagues for their assistance in an experiment that might have contributed to "the improvement of knowledge, such especially as might possibly be of use to men in situations of distress."

No important improvement on Franklin's experiments was made for more than one hundred years. Then, in 1891, Miss Agnes Pockels, an untrained German amateur experimenter, began the investigations of the properties of water surfaces which directed Lord Rayleigh to the conception of unimolecular layers. W. B. Hardy, I. Langmuir, and others have in the last quarter of a century widely extended these researches, which now have the highest practical significance.

The theory of the chemistry and physics of surfaces was founded by Franklin and still includes his ideas. It is of fundamental importance in many industrial and biological processes, and is one of the most important branches of modern science.

Franklin proposed *An Abridgment of the Book of Common Prayer* in 1773. He had noticed the declining attendance at church, so he prepared a shorter and simpler scheme of common prayer. He rationalized the Prayer Book. The proposal failed completely. Franklin apparently forgot that men do not expect intelligent religion. They do not go to religion for persuasion, but for emotional support. The incident shows he was extremely non-mystical.

Franklin had become an established figure in London since his arrival in 1757. Owing to his skilful representation of the interests of the colonies he gradually became their mouthpiece in England. His discreet personality attracted a group of social friends, and his contributions to science and social philosophy secured him a much respected position in the circles of the Royal and other learned societies.

Faÿ has emphasized the value of his connection with the Freemasons. This consolidated his position.

Its full strength was suddenly revealed in 1774, by the affair of the Hutchinson letters. These had been written by born Americans, urging the British Government to force their countrymen to accept taxation by the House of Commons, without representation in that body. Hutchinson wrote that "there must be an abridgment of what are called English liberties ; for a colony cannot enjoy all the liberty of a parent state."

Franklin obtained these letters by means which have never been explained, and sent them to New England, for confidential inspection by a few of the leading politicians. A knowledge of their contents spread, and presently they were published, contrary to Franklin's instructions. Franklin said he thought that if the American protestors knew some influential American-born citizens were advising the British Government to use force against them, they would become more patient with the British Government, recognizing that it had been misled by some of their own people. The event did not promote peace, as Franklin had expected, but raised fury on both sides of the Atlantic. The Americans were furious with the machinations against them, and the British Government were furious that the contents of such secret documents had become public.

The British Government made Franklin submit to a public examination concerning his conduct in the affair. He was called before the Privy Council, consisting of the Lord President, the Secretaries of State, and many other Lords. A number of distinguished visitors such as Edmund Burke and Joseph Priestley were in the public audience. The examination was conducted by the Attorney-General, Wedderburn, with the extremest personal abuse, and the President did not trouble to preserve decorum among the members of the council, who laughed and clapped at the Attorney-General's witticisms.

Franklin wore "a full-dress suit of spotted Manchester velvet, and stood conspicuously erect, without the smallest movement of any part of his body. The muscles of his face had been previously composed, so as to afford a placid, tranquil expression of countenance, and he did not suffer the slightest alteration of it to appear during the continuance of the speech."

This event destroyed Franklin's hopes for the creation of an empire of British commonwealths. It finally convinced him that the governing classes of Britain were not to be persuaded into a progressive imperial policy. Further, the personal insults showed that he could no longer hope to be personally assimilated into the British upper classes. His recognition of the permanency of his exclusion from those classes helped to intensify that part of the Anglo-American conflict which involved struggles between different social classes. Britain's snub to Franklin was not only a snub to America, but from a merchant-landowner class to a class of relatively small property owners. The bitterness of the Anglo-American contest was increased by the psychology of class conflict. The American governing classes resented the assumption of superior social status by the English governing classes as much as the English attempts to tax their property. If the Americans had been allowed to feel that the contest was between two groups of gentlemen of equal status for a rich prize, they would perhaps have compromised without independence. But the English would not accept the American leaders as gentlemen. This class division added class hatred to the other motives for dispute, and made the combatants far more implacable.

Franklin felt he had been stupidly and unjustly treated, as indeed he had, even from the point of view of the British governing classes, and the collapse of his political and social aspirations converted him into a relentless enemy.

The British Government withdrew their recognition of his status as a colonial agent, and dismissed him from his position of Deputy Postmaster General of the colonies.

Franklin described to Joseph Priestley in 1774 his recognition of the existence of marsh gas. When passing through New Jersey in 1764 friends told him that if a lighted candle were applied near the surface of certain rivers, "a sudden flame would catch and spread on the water, continuing to burn for near half a minute."

His philosophical friends in England were incredulous. Finley of New Jersey sent the following letter to the Royal Society in 1765 : " A worthy gentleman, who lives a few miles' distance, informed me that in a certain small cove of a mill-pond, near his house, he was surprised to see the surface of the water blaze like inflamed spirits. I soon after went to the place, and made the experiment with the same success. The bottom of the creek was mudded, and when stirred up, so as to cause a considerable curl on the surface, and a lighted candle held within two or three inches of it, the whole surface was in a blaze, as instantly as the vapor of warm inflammable spirits, and continued, when strongly agitated, for the space of several seconds. It was at first imagined to be peculiar to that place ; but upon trial it was soon found that such a bottom in other places exhibited the same phenomenon. The discovery was accidentally made by one belonging to the mill."

The letter was read to the Royal Society in 1765, but deemed beyond credulity, so it was not printed.

Comparisons of the chemical constitution of olefiant gas and marsh gas gave John Dalton valuable inspiration in his development of the atomic theory of chemistry. He showed that the marsh gas contained exactly twice as much hydrogen as the olefiant gas for equal contents of carbon. This whole-number relation suggested to him that ultimate particles of marsh gas contained one atom of carbon and two of hydrogen, while the ethylene particle contained one of each.

Marsh gas occupies an important position in the history of chemical theory, because its constitution could be easily compared with that of other gases containing the same constituents in different proportions, and led to the discovery of the chemical Law of Multiple Proportions ; that if two elements combine to form more than one compound, then the weights of one of those elements that combine with a fixed weight of the other bear a simple ratio.

The nature of the origin of marsh gas was also important. As it was found in ditches and marshes, it was particularly apt to interest the self-taught meteorologist and observer of the country-side, John Dalton. He extracted a large part of the atomic theory out of marsh gas because it came from phenomena of the countryside with which he had a profound acquaintance. His discovery of the Law of the Partial Pressures of Gases arose out of his prolonged studies of the properties of the air, in connection with the weather.

Franklin and Dalton surpassed the London fellows of the Royal Society in being able to recognize the reality of peculiar phenomena. Franklin's recognition that the "will o' the wisp," or flame that flitted over marshes, was an example of gaseous combustion and not a strange illusion, is a parallel to his recognition of the material nature of the flashes of lightning. It is interesting to note that he twice detected the material reality under natural flame phenomena, with lightning and with marsh gas. He had the power of viewing common things without common illusions, which is one of the rarest intellectual gifts.

Franklin's capacious intellect could advance and follow all these matters, even in the midst of increasing political tension and political labours. He could still find energy to keep contact with the formative personalities of the time, besides the established politicians and scientists. Tom Paine made his acquaintance and sailed for America in 1774, with introductions from him. Franklin became the world's intellectual exchange in the third quarter of the eighteenth century.

The dispute between England and America deepened. The English insisted on the Americans accepting tea subject to an import duty from the East India Company. This company had at least seventy nominees who had been bribed into membership of the House of Commons. The Americans preferred not to consume tea which had been taxed without their consent, so they boycotted English tea, and either went without tea, or obtained it from smugglers. The effects of the boycott on the East India Company, and thence on British commerce generally, were profound. The company was left with four million pounds' worth of tea in its warehouses, and the price of its stock fell from 280 to 160, occasioning private bankruptcies and distress. The Government then arranged for the company's tea to be sold duty-free in certain American ports, but without technically repealing the tax. A consignment of tea arived in Boston. The infuriated population, led by some of the richest citizens, prevented it from being landed, and a number of persons in disguise threw the tea into the harbour.

These events were followed by military action against the Bostonians by the forces of the British Government.

War between England and the colonies became imminent. Franklin made a last effort to move all influences for peace. He succeeded in meeting Chatham, who had evaded him for eighteen years. The Imperialist statesman considered that the unity of the empire was ultimately more valuable financially, and in every way, than the disputed interests of the moment. He was quite willing to allow considerable self-government to the constituent colonies, but was absolutely against independence.

Franklin helped Chatham with the notes for his speeches against British military compulsion. They complimented each other on their similar ideals for the future of the British Empire, and Franklin assured him that he had never met anyone in America, drunk or sober, who desired independence. It is impossible to believe that Franklin did not deceive Chatham on this point. But Chatham would not proceed without the assurance, so Franklin gave it, and hoped for the best.

He drew up schemes of reconciliation for the secret consideration of the British Government. One of these contained a series of articles, of which the twelfth is particularly interesting. This concerns the conditions of appointment of judges. These were formerly appointed by the crown and paid by the assemblies. The duration of the appointment was decided by the crown, and the duration of the salary by the assemblies. It had been urged against the assemblies that they exerted undue influence over the courts of justice through their control of judges' salaries. The assemblies replied that making them dependent on the crown for the continuance of their places allowed the crown an undue influence; "that one undue influence was a proper balance for the other." The assemblies would grant permanent salaries to the judges, if the crown would consent to retain judges only during *good behaviour*.

This passage shows the notion of a balance of forces was included in the mechanism of the proposed administrative arrangements.

Chatham moved in the House of Lords of January 20th, 1775, that the British army should be removed from Boston in order to "allay ferments and soften animosities." Franklin writes that he "was quite charmed with Lord Chatham's speech in support of his motion. He impressed me with the highest idea of him, as a great and most able statesman." He informed Chatham that "he has seen, in the course of life, sometimes eloquence without wisdom, and often wisdom without eloquence; in the present instance he sees both united, and both, as he thinks, in the highest degree possible." It is said that Chatham concluded his speech: "If the ministers thus persevere in *misadvising* and *misleading* the king, I will not say that they can alienate the affections of his subjects from his crown, but I will affirm that they will make the crown *not worth his wearing*. I will not say that the king is betrayed, but I will pronounce that *the kingdom is undone*."

"The motion was rejected. Sixteen Scotch peers, and twenty-four bishops, with all the lords in possession or expectation of places, when they vote together unanimously, as they generally do for ministerial measures, make a dead majority, that renders all debating ridiculous in itself." Chatham was ill, and had lost favour, and was at the end of his career. His last actions showed that his former evasion of Franklin had been an evasion of the American problem, and that his judgment of that problem had been profoundly faulty.

After this, Franklin could do little more, so he sailed for America, not without fear of arrest, and announcing that the death of his wife in 1774 required his return for the settlement of his affairs. They had been parted for nearly ten years. Franklin had corresponded with her loyally, but not very ardently. He had not seemed to mind whether she was in America or England. While he had quite liked her, he was probably not sorry that she had not encumbered his European diplomatic movements.

When he arrived in America he was welcomed by his daughter Sarah, who had become the head of his household. She had married Richard Bache in 1767. The sole surviving descendants of Franklin came through her line. She looked after him during his last years.

The colonies had organized a congress at Philadelphia of leading representatives to discuss what should be done. When Franklin arrived, he was appointed a delegate for Pennsylvania.

He had spent part of his time on the journey over the Atlantic observing the temperature and appearances of the water in the Gulf Stream.

Shortly before his arrival in America, fighting between English soldiers and Americans started at Lexington. Franklin threw himself into the work of defence. *Chevaux-de-frise* were constructed in the River Delaware according to his design, which retarded the advance of the British ships for two months.

The Congress declared the Independence of the United States of America in 1776. They needed aid desperately, for they were fighting the most formidable power in the world. They naturally decided to send Franklin, their most famous citizen, to solicit it. He sailed again for Europe, to collaborate with Deane and Lee in the negotiation of a treaty of commerce and friendship with France. The success of the American insurrection depended on French aid, and therefore on Franklin, who was the leading personality among the commissioners. He was nearly seventy years old when he set forth on this tremendous task.

The commissioners struggled against the lack of confidence of the French in the future of the United States. The French wanted their traditional enemy to be weakened, but were anxious not to support a losing cause. Unofficial methods of helping the Americans with money were devised by Beaumarchais, but the French would not give more official assistance until they could see more clearly how the contest would end. Franklin, Deane and Lee lived in the midst of a clash of social forces which were to determine the paths of empires and of English and French cultures. Their status was not recognized, and they had little money to finance their activities.

The influence of personalities on the direction of social affairs is often exaggerated, but in some situations it may be great. The balance of social forces in an unstable equilibrium provides such a situation. The French could not make up their minds whether to support the Americans as full allies. While they were trying to decide, the extraordinary personality of Franklin was constantly before them, as an advertisement of a nation. He was even more famous among French than among other scholars. His electrical researches had at first been appreciated better in France than in England. Besides his fame, he possessed extraordinary vitality. His mind was twenty years younger than his age. He behaved with extreme discretion and modesty, he had social charm, and adapted himself apparently without effort to the manners of the French. Yet the structure of his culture was different from that of the French or the English. Talleyrand said he was remarkable in conversation because of his simplicity and the evident strength of his mind.

Franklin was the first important ambassador of a new nation, and he appeared to be a superman. Presumably other supermen might be found in the place where he came from, so the people he represented were not to be abandoned without much deliberation.

Franklin was the living advertisement of the present and future greatness of America. He fascinated the French while they deliberated. After nearly two years, Washington captured Burgoyne's army at Saratoga. The French now had courage to give the Americans full support. Franklin's rôle and task became more normal. He had to deal with exceedingly complicated diplomatic manœuvres, spying and intrigue, but it was no longer necessary for him to appear as a magician or superman. His long experience of difficult negotiations, his mastery of journalism and Freemasonry, his intellectual prestige, his understanding of a wide variety of special subjects, enabled him gradually to solve the diplomatic problems.

Franklin's difficulties in Paris were vastly increased by difficulties with his colleagues. The complicated diplomatic and financial manœuvres were beyond Deane's comprehension. Deane could not give a satisfactory account of the financial arrangements, and was suspected of speculation. Arthur Lee was the son of Virginian slave-owners, and had been educated at Eton. He was a member of the governing classes by birth, and was separated by the traditions of class behaviour from Franklin, who had been born in the lower middle class, and had become a member of the governing classes through inherent ability, and not through the possession of traditional governing class position and habits. Lee wished to conduct American affairs in Paris like a man accustomed to government, with aristocratic manners. His class sensitivity was increased by a morbidly suspicious temperament. He suspected the discreet and subtle habits that Franklin had had to acquire in order to rise to power. He believed that Franklin was liable to sell the United States to England or France, and communicated his suspicions to powerful groups in Congress. He even directly suggested that Franklin should be recalled, in favour of himself.

The efficiency of the British spying system in Paris was remarkable. A large fraction of the American Commissioners acquaintances were in English pay. Great efforts were made after Saratoga to persuade Franklin and his colleagues to accept peace terms which would concede nearly everything except independence and alliance with France.

George III and his advisers sent peace commissions to America partly to avoid negotiating with Franklin. The king wrote to his prime minister, " The many instances of the inimical conduct of Franklin towards this country make me aware that hatred of this country is the constant object of his mind, and therefore I trust that, fearing the rebellion, colonies may accept the generous offers I am enabled by Parliament to make them by the Commissioners now to be sent to America that his chief aim in what he has thrown out is to prevent their going. . . . Yet I think it so desirable to end the war with that country, to be enabled, with redoubled ardor, to avenge the faithless and insolent conduct of France, that I think it may be proper to keep open the channel of intercourse with that insidious man."

Franklin's hatred of the British governing classes was born during his abuse before the Privy Council by Wedderburn.

When he went to Versailles to sign the treaty with France, he wore the "full-dress suit of spotted Manchester velvet," which he had not worn after he had been insulted in it, and he never wore it again after the occasion of the signature of the treaty.

Franklin continued his philosophic interests in the midst of his great diplomacy. He attended the Academy of Sciences regularly. He read a paper on the Aurora Borealis in 1779. He ascribed it to the action of electricity in the upper atmosphere, which, being at a low pressure, would be a good conductor of electricity. He supposes the electricity is brought into the polar regions on the raindrops of clouds, which drift there with the hot air rising from the tropics and falling near the poles. Atmospheric electricity is normally able to escape in lightning discharges, but cannot so escape in the polar regions, he believes, because those regions are covered with ice, which is a non-conductor. The melting of the ice-cap in summer would explain why the Aurora is weaker in summer than in winter.

He supposes that the polar air owing to its extra density offers more resistance to the electric matter passing through it, and thus makes it visible.

"The rays of electric matter issuing out of a body, diverge by mutually repelling each other, unless there be some conducting body near to receive them ; and if that conducting body be at a greater distance, they will *first diverge*, and then *converge*, in order to enter it. May not this account for some of the varieties of figure seen at times in the *motions* of the luminous matter of the aurorae ?"

Franklin is here using the notion of lines of force.

About the same time he wrote to the *Journal of Paris* about "An Economical Project." This was a suggestion of systematic early rising in order to use daylight fully and save the cost of illumination. He calculates "that the city of Paris might save every year by the economy of using sunshine instead of candles" the sum of $25,000,000, or £5,000,000.

He proposes to make the people rise early by taxing window shutters, restricting the sale of candles, stopping vehicular traffic after dark, and ringing church bells at dawn.

The plan of advancing time by the clock, as in the modern systems of Summer Time, apparently did not occur to him. The proposal of systematic daylight saving by the son of a candle-maker is an example of the influence of industrial experience on the conception of inventions for the improvement of the organization of social life.

In 1779 Franklin issued a general order to the captains of American ships to give a safe passage to Captain Cook, whose return from his last world voyage was expected. Franklin believed science, medicine, and even all productive labour should be exempt from interference during war. He persuaded the Congress not to put an embargo on the import of English scientific instruments and learned books, and was proud of incorporating a similar provision in the Constitution of Pennsylvania.

Franklin's interest in economics procured him the friendship of the French physiocrats and economists. His belief in the superiority of farming to industry as a foundation of society agreed with that of the physiocrats. As Faÿ remarks, the French liberal economists drew him away from the ideas of the British mercantile economists. But Franklin had emancipated himself before he met them. The French economic thinkers did not provide him with principles, but added enthusiasm to them. Franklin showed more optimistic belief in humanity after his contact with the French, but not a new economic philosophy.

He wrote from France in 1779 concerning the liquidation of the national debt by the depreciation of paper money :

" This effect of paper currency is not understood on this side the water. And indeed the whole is a mystery even to the politicians, how we have been able to continue a war four years without money, and how we could pay with paper that had no previously fixed fund appropriated specifically to redeem it. This currency, as we manage it, is a wonderful machine. It performs its office when we issue it ; it pays and clothes the troops and provides victuals and ammunition ; and when we are obliged to issue a quantity excessive, it pays itself off by depreciation."

Franklin's remarks on " managed currency " and its value in social crises have a modern air.

Franklin continued to correspond with Priestley, Price, and other English protestant philosophers.

" Dr. Priestley, you tell me, continues his experiments with success. We make daily great improvements in *natural*—there is one I wish to see in *moral*—philosophy : the discovery of a plan that would induce and oblige nations to settle their disputes without first cutting one another's throats."

He writes to Priestley: "I always rejoice to hear of your being still employed in experimental researches into nature, and of the success you meet with. The rapid progress *true* science now makes, occasions my regretting sometimes that I was born so soon. It is impossible to imagine the height to which may be carried, in a thousand years, the power of man over matter. We may perhaps learn to deprive large masses of their gravity, and give them absolute levity, for the sake of easy transport. Agriculture may diminish its labor and double its produce; all diseases may by sure means be prevented or cured, not excepting even that of old age, and our lives lengthened at pleasure even beyond the antediluvian standard. O that moral science were in as fair a way of improvement, that men would cease to be wolves to one another, and that human beings would at length learn what they now improperly call humanity!"

"The greatest discovery made in Europe for some time past is that of Dr. Ingenhousz's relating to the great use of the leaves of trees in producing wholesome air."

Then he describes Rochon's invention of a range-finder based on the double refraction by Iceland spar.

The anti-Catholic Gordon riots occurred in London in 1780. Franklin wrote to a friend: "The beginning of this month, a mob of fanatics, joined by a mob of rogues, burned and destroyed property to the amount, it is said, of a million sterling." After these riots Gibbon wrote: "Our danger is at an end, but our disgrace will be lasting, and the month of June 1780 will ever be marked by a dark and diabolical fanaticism which I had supposed to be extinct, but which actually subsists in Great Britain perhaps beyond any other country of Europe."

Franklin and Gibbon were in some agreement on the Gordon riots, but on each other they were not. Franklin once found that Gibbon was staying in an inn at which he had just arrived. He sent an invitation to Gibbon, who was upstairs, to spend the evening with him, and received the answer that it was impossible to converse with a "revolted subject." Franklin replied that when "the decline and fall of the British Empire should come to be his subject," he "would be happy to furnish him with ample material which was in his possession."

Franklin objected to religious tests for citizenship and appointments. "I think they were invented not so much to secure religion itself as the emoluments of it."

Some experiences with the swelling of mahogany wood i Europe drew his attention to the humidity of the air. H remarks : " The greater dryness of the air in America appear from some other observations. . . ."

Veneer woods which were durable in Europe " never woul stand with us," the thin sheets shrank, and " were for eve cracking and flying."

" In my electrical experiments there, it was remarkable tha a mahogany table, on which my jars stood under the prim conductor to be charged, would often be so dry, particularl when the wind had been some time at northwest, which wit us is a very drying wind, as to isolate the jars." . . .. " I had like table in London . . . but it was never so dry as to refus conducting the electricity."

In 1781 Franklin found himself " rather inclined to adop that modern " view " which supposes it best for every countr to leave its trade entirely free from all incumbrances."

During a visit to Hanover, he met an educated man, wh subsequently applied to him for a place as a soldier. H remarked that he could not " conceive what should reduce hin to such a situation as to engage himself for a soldier."

The difficulties of the American commissioners in thei negotiations and between themselves became almost unman ageable. Lee was recalled and Franklin offered to resign Deane was recalled owing to misunderstandings of his affairs Franklin's offer was not accepted, and Adams and Jay were sent to join Franklin and Lee as commissioners with authority to make peace with England when permissible. The quarrels continued almost as ferociously. Adams was a very able man The appointment of Washington as commander-in-chief of the American Army was chiefly due to him, and he was probably the most influential politician in Congress. Though extremely honest, Adams was introspective and sensitive. He was little and fat, and was unable to carry off his appearance without looking slightly comic. Paris could not imagine that he could be more important in American home politics than such an immense personality as Franklin. Adams did not receive very much notice. He felt slighted. He was also inexperienced in the technique of European diplomacy. When he asserted himself the French objected to his diplomatic manners. This increased his anger, and his introspective suspicions. His psychological state had put him in sympathy with Lee. Further, his principles of social philosophy were far nearer to Lee's than to Franklin's.

A measure of Franklin's discretion and diplomatic subtlety is given by his skilful management of this very difficult situation. Adams was perhaps the most powerful American of the moment, but Congress decided that Franklin must become the sole American ambassador to France, while Adams was appointed to Holland, and Jay to Spain.

Franklin had always been susceptible to attractive women. His amiability was an essential factor in his marvellous success at Paris. He was very friendly with the widow of the philosopher Helvetius, and may have proposed to her when he was seventy-five. In one of his letters to her, he discussed why her house was one of the most distinguished and frequented salons in Europe. He ascribed it to her power of making everyone feel happy there.

Mrs. John Adams, who in her own style was also a charming woman, wrote of a visit to Mme. Helvetius : " She entered the room with a careless, jaunty air ; upon seeing ladies who were strange to her, she bawled out, ' Ah ! mon Dieu, where is Franklin ? Why did you not tell me there were ladies here ? ' You must suppose her speaking this in French. ' How I look ! ' said she, taking hold of a chemise made of tiffany, which she had on over a blue lutestring, and which looked as much upon the decay as her beauty, for she was once a handsome woman ; her hair was frizzled ; over it she had a small straw hat, with a dirty gauze half-handkerchief round it, and a bit of dirtier gauze than ever my maids wore was bowed on behind. She had a black gauze scarf thrown over her shoulders. She ran out of the room ; when she returned, the Doctor entered at one door, she at the other ; upon which she ran forward to him, caught him by the hand, ' Hélas ! Franklin ' ; then gave him a double kiss, one upon each cheek, and another upon his forehead. When we went into the room to dine, she was placed between the Doctor and Mr. Adams. She carried on the chief of the conversation at dinner, frequently locking her hand into the Doctor's, and sometimes spreading her arms upon the backs of both the gentlemen's chairs, then throwing her arm carelessly upon the Doctor's neck.

" I should have been greatly astonished at this conduct, if the good Doctor had not told me that in this lady I should see a genuine Frenchwoman, wholly free from affectation or stiffness of behaviour, and one of the best women in the world. For this I must take the Doctor's word ; but I should have set her down for a very bad one, although sixty years of age, and a widow. I own I was highly disgusted, and never wish for an acquaintance with any ladies of this cast. After dinner she threw herself upon a settee, where she showed more than her feet. She had a little lap-dog, who was, next to the Doctor, her favourite. This she kissed, and when he wet the floor she wiped it up with her chemise. This is one of the Doctor's most intimate friends with whom he dines once every week, and she with him. She is rich, and is my near neighbour; but I have not yet visited her. Thus you see, my dear, that manners differ exceedingly in different countries. I hope, however, to find amongst the French ladies manners more consistent with my ideas of decency, or I shall be a mere recluse."

Franklin was informed of the defeat of Cornwallis, and the virtual collapse of the British campaign, in the autumn of 1781. The long negotiations for the final peace commenced. Of the English he wrote: "though somewhat humbled at present, a little success may make them as insolent as ever. I remember that, when I was a boxing boy, it was allowed, even after an adversary said he had enough, to give him a rising blow. Let ours be a douser."

He took shares in the newly-formed National Bank.

He restrained Congress from asking too much of the French. "This is really a generous nation, fond of glory, and particularly that of protecting the oppressed. Trade is not the admiration of their noblesse, who always govern here. Telling them their *commerce* will be advantaged by our success, and that it is their interest to help us, seems as much as to say, 'Help us, and we shall not be obliged to you.' Such indiscreet and improper language has been sometimes held here by some of our people, and produced no good effects."

A friend sent him a copy of Cowper's poems. "The relish for reading poetry had long since left me; but there is something so new in the manner, so easy and yet so correct in the language, so clear in the expression, yet concise, and so just in the sentiments, that I have read the whole with pleasure, and some pieces more than once."

In 1782 Franklin wrote to Priestley that he would rejoice if he could recover the leisure to search "into the works of nature; I mean the *inanimate*, not the *animate* or moral part of them; the more I discovered of the former, the more I admired them; the more I know of the latter, the more I am disgusted with them. Men I find to be a sort of beings very badly constructed, as they are generally more easily provoked than reconciled, and more disposed to do mischief to each other than make reparation. . . ." He suggests that as Priestley grows older he may " repent of having murdered in mephitic air so many honest, harmless mice, and wish that, to prevent mischief, you had used boys and girls instead."

A few days later he writes to another friend " I have been apt to think that there has never been, nor ever will be, any such thing as a *good* war, or a *bad* peace."

The peace negotiations between America, England, and France dragged on and on, and were conducted with suspicion and clumsiness by every participating government.

At the age of seventy-six years, Franklin had to exert intellectual direction over the conflicting political forces. His mental alertness and vigour in these affairs were quite extraordinary, but few persons, especially his American colleagues, understood that his physical lassitude, partly due to gout, and partly to " diplomatic illnesses " for bluffing negotiators, did not reflect the activity of his political intelligence. He was accused of apathy in his country's cause.

Franklin's colleague Jay was of Huguenot descent, and like Adams a Puritan. He had an excellent character, but his traditions excited suspicion against the French Catholic monarchist politicians. Though his temperament was more amiable than Adams', his political principles were fundamentally similar. He is reported to have said in negotiations with an English peace commissioner concerning security for the guarantee of peace that " he would not give a farthing for any parchment security whatever. They had never signified anything since the world began, when any prince or state, of either side, found it convenient to break through them. But the peace he meant was such, or so to be settled, that it should not be the *interest* of either party to violate it. This, he said, was the only security that could be proposed to prevent those frequent returns of war, by which the world was kept in continual disturbance."

Almost at the same moment, Franklin was assisting a poor peasant from Provence to publish schemes for making peace treaties durable, and was trying to have privateering outlawed in warfare between nations.

The lawyer Jay had no faith in international law, while Franklin hoped that the cruelty of war might be mitigated by the gradual extension of agreed prohibitions on violence against civilians.

Franklin continued to follow his scientific interests. He discussed the reports of live toads being found in stone, and how long they might have been there. Pringle had written to him in 1780 :

> Sir :—Last year I had the honor to inform you that two of those large moths called Muskitoe Hawks, which appear about September, and disappear about the beginning of December, lived seventy-one days after I had cut their heads off with a pair of scissors.

In 1782 he outlined a nebular theory of the origin of the earth, to account for the facts of geology, such as buried coal strata. " I should conceive, that, all the elements in separate particles being originally mixed in confusion, and occupying a great space, they would (as soon as the almighty fiat ordained gravity, or the mutual attraction of certain parts, and the mutual repulsion of others, to exist) all move to their common centre.

" The original movement of the parts towards their common centre would naturally form a whirl there." He is pleased to hear of the " ferruginous nature of the lava which is thrown out of the depths of our volcanoes.

" It has long been a supposition of mine that the iron contained in the surface of the globe has made it capable of becoming, as it is, a great magnet ; that the fluid of magnetism perhaps exists in all space ; so that there is a magnetical north and south of the universe as well as of this globe, and that, if it were possible for a man to fly from star to star, he might govern his course by the compass ; that it was by the power of this general magnetism this globe became a particular magnet."

He supposes the shape of the earth may have been changed by shifts of the axis. As the equatorial diameter is many miles greater than the polar, this would produce flooding by the sea, and the laying of new strata on the tops of old mountains.

The contact of water and fire under the earth may produce explosive shocks that send waves through the " internal ponderous fluid." These waves will pass under all countries, and shake them.

" Men cannot make new matter of any kind."

In 1783 he corresponded with the Italian scholar Filangieri on the principles of the American Constitutions. According to Bigelow, it is said that the correspondents became impressed by the American concern to place restrictions on the popular will, while the European philosophers and democrats wished to abolish such restrictions.

The quarrel between Adams and Franklin became public in 1783. Adams abused the intentions of the French minister de Vergennes, even in front of English ministers, and had for years been attacking Franklin through his friends and relatives in Congress. Franklin had hitherto ignored these attacks, but at last he had to warn the Congress against Adams' attacks. He summarized their nature, and then delivered an immortal judgment of his able colleague :

" I am persuaded, however, that he means well for his country, is always an honest man, often a wise one, but sometimes, and in some things, absolutely out of his senses."

In spite of the most distracting political quarrels, and his age, he preserved his interest in science.

The Brothers Montgolfier demonstrated their hot-air balloon in 1783. The invention excited great interest, and later in the year Saint Fond, the Roberts, and Charles constructed a varnished silk balloon filled with hydrogen manufactured by treating iron filings with weak sulphuric acid. The diameter of the balloon was twelve feet. It was released in Paris before an enthusiastic crowd of five thousand persons, including Franklin. An attached note requested the finder to return the balloon. It fell twelve miles distant, and was reported to contain some ice.

Franklin sent lively descriptions of the experiments to Sir Joseph Banks, the President of the Royal Society, and subscribed to funds for further experiments. He immediately considered that the invention " may pave the way to some discoveries in natural philosophy of which at present we have no conception." He thought that persons might bound across the country attached to small balloons, so that they would press the earth with a weight of not more than ten pounds. Horses might be assisted in the same way. Water might be frozen by hauling it up to a captive balloon, and persons might be given a view of the country from a height of one mile, for a guinea, etc.

" A few months since the idea of witches riding thro' the air upon a broomstick, and that of philosophers upon a bag of smoke, would have appeared equally improbable and ridiculous.

" These machines must always be subject to be driven by the winds. Perhaps mechanic art may find easy means to give them progressive motion in a calm, and to slant them a little in the wind.

" Beings of a frank and (*sic*)nature far superior to ours have not disdained to amuse themselves with making and launch balloons, otherwise we should never have enjoyed the li of those glorious objects that rule our day and night, nor ha had the pleasure of riding round the sun ourselves upon balloon we now inhabit."

Franklin sent an admirable description of the ascent Charles and Robert to Banks. "Never before was a phi sophical experiment so magnificently attended."

A small balloon fell in a direction contrary to that of t ground wind. Franklin remarks that a knowledge of t different directions of winds at different heights "may be use to future aërial voyagers."

He wrote to Ingenhousz that ballooning appears "to b discovery of great importance, and what may possibly give new turn to human affairs. Convincing sovereigns of t folly of wars may perhaps be one effect of it, since it will impracticable for the most potent of them to guard his domi ions. Five thousand balloons, capable of raising two m each, could not cost more than five ships of the line, and whe is the prince who can afford so to cover his country with troo for its defense as that ten thousand men descending from th clouds might not in many places do an infinite deal of mischi before a force could be brought together to repel them ? "

Franklin's previsions of the possibilities of aerial warfa have been fulfilled brilliantly. The military experiments landing hundreds of troops behind the supposed enemy's lin by parachutes are today familiar to the newspaper reader.

He reports to Ingenhousz that Morveau has proposed fil ing the balloons with gas "made from sea coal"—coal-gas

Owing to his interest in balloons, he received "a letter i France, the first through the air, from England." Thu Franklin received the first Anglo-French air-mail delivery.

Meanwhile the definitive peace treaties between all th belligerent powers were signed at last, in September, 1783.

News from America that the people are remiss in payin taxes prompts him to express his conception of property.

"All property, indeed, except the savage's temporary cabi and other little acquisitions absolutely necessary for his sub sistence, seems to me the creature of public convention. Henc the public has the right of regulating descents, and all othe conveyances of property, and even of limiting the quantity an uses of it. All the property that is necessary to a man, for th conservation of the individual and the propagation of th species, is his natural right, which none can justly deprive hi of ; but all property superfluous to such purposes is the property of the public, who, by their laws, have created it, and who may therefore by other laws dispose of it, whenever the welfare of the public shall demand such disposition. He that does not like civil society on these terms, let him retire and live among savages. He can have no right to the benefits of society who will not pay his club towards the support of it."

Franklin was visited in 1783 by Baynes and Romilly, who were then young men. Bigelow quotes Baynes' notes of their conversations. Franklin discussed the plans of Price and others for a general peace in Europe. He thought it would be difficult to persuade the various sovereigns to send delegates to one place " but if they would have patience, I think they might accomplish it, agree upon an alliance against all aggressors, and agree to refer all disputes between each other to some third person, or set of men, or power. Other nations, seeing the advantage of this, would gradually accede ; and perhaps in one hundred and fifty or two hundred years, all Europe would be included."

Franklin's lower limit for the date of a successful league of nations was 1933. The event showed his estimate was partially correct ; perhaps by 1983 it will have become adequately verified.

Samuel Romilly, the English legal reformer, wrote in his diary : " Of all celebrated persons whom in my life I have chanced to see, Dr. Franklin, both from his appearance and his conversation, seemed to me the most remarkable. His venerable patriarchal appearance, the simplicity of his manner and language, and the novelty of his observations, at least the novelty of them at that time to me, impressed me with an opinion of him as one of the most extraordinary men that ever existed."

Franklin read to him some passages from the American Constitutions, and expressed surprise that the French Government had allowed them to be published. They made a " very great sensation in Paris, the effects of which were felt many years afterwards."

The psychologist and charlatan, Mesmer, appeared in Paris in 1784. He became very fashionable, and was supported by Lafayette and other eminent persons. The Academy of Sciences was requested by the King to report on Mesmer's claims. Franklin and Lavoisier were appointed members of the committee of investigation. Mesmer refused to make any experiments under expert observation, but his disciple Desson offered to make demonstrations. These were done at Franklin's garden at Passy. The investigators easily proved that Desson consciously or unconsciously attempted to deceive the audience. Franklin pointed out in an unpublished paragraph of the report the relation between the emotionalism of the mesmerists and eroticism. Mesmer fled, discredited, but his pupil de Puysegur demonstrated some of the phenomena of hypnosis, such as controlled automatism and insensibility to pain, in 1785. Franklin helped to expose the mistakes, or swindling in mesmerism, but he did not help the recognition of its valuable part, which was an important psychological discovery.

Franklin was interested in the improvement of the technique of printing. French printers had proposed that type containing groups of letters should be used in order to save time in composition. Franklin devised his own scheme of "logography," as it is called. John Walter, the founder and printer of the London *Times*, discussed logography with Franklin and originally printed the journal with such type. The experiment was expensive, and unsuccessful, as the time saved in composition was lost in distributing the type.

Franklin was asked in 1784 by the American astronomer Rittenhouse to describe his speculations on the nature of light and matter. His reply contained expressions of scientific faith which form an interesting parallel with the famous address given by Faraday at the Royal Institution in 1846. A lecturer was unable to fulfil his engagement, so at the last moment Faraday offered some extempore "Thoughts on Ray-vibrations." One of these consisted of the electro-magnetic wave-theory of light : "The view which I am so bold as to put forth considers, then, radiation as a high species of vibration in the lines of force, which are known to connect particles and also masses of matter together. It endeavours to dismiss the ether, but not the vibrations."

Franklin suggested that "universal space, as far as we know it, seems to be filled with a subtile fluid, whose motion, or vibration, is called light.

"The power of man relative to matter seems limited to the dividing it, or mixing the various kinds of it, or changing its form and appearance by different compositions of it, but does not extend to the making or creating of new matter, or annihilating the old. Thus, if fire be an original element, or kind of matter, its quantity is fixed and permanent in the world."

The germs of the theories of the conservation of mass and energy are seen in these notions.

Franklin suggested in 1784 for the first time in Europe or America the use of water-tight bulkheads in the construction of ships. He had had some part in the management of the packet or postal and message boat service between England and America, so he had had some professional interest in ships. When the French proposed to start a packet service after the peace, he advised that " as these vessels are not to be laden with goods, their holds may, without inconvenience, be divided into separate apartments after the Chinese manner, and each of those apartments caulked tight so as to keep out water. In which case if a leak should happen in one apartment, that only would be affected by it, and the others would be free ; so that the ship would not be so subject as others to founder and sink at sea. This being known would be a great encouragement to passengers."

Franklin invented bifocal spectacles. He describes in 1785 how he was prompted to do so. " I had formerly two pairs of spectacles, which I shifted occasionally, as in travelling I sometimes read, and often wanted to regard the prospects. Finding this change troublesome, and not always sufficiently ready, I had the glasses cut, and half of each kind associated in the same circle. By this means, as I wear my spectacles constantly, I have only to move my eyes up or down, as I want to see distinctly far or near, the proper glasses being always ready. This I find more particularly convenient since my being in France, the glasses that serve me best at table to see what I eat not being the best to see the faces of those on the other side of the table who speak to me ; and when one's ears are not well accustomed to the sounds of a language, a sight of the movements in the features of him that speaks helps to explain ; so that I understand French better by the help of my spectacles."

Franklin left Europe in 1785. His health had become weak, as he suffered from gall-stones. He could not walk much, nor ride on horseback, nor in an ordinary carriage. On his departure he received magnificent expressions of regard and honour, and was carried in the Queen's litter to his ship.

At Southampton he was met by his son, who had recently revived relations with him. His reply to his son's letter contains expressions of his views on the involuntary nature of human opinions, and the relations between personal and political duties. He wrote that the meeting would be very agreeable to him. “ Indeed, nothing has ever hurt me much, and affected me with such keen sensations, as to fi myself deserted in my old age by my only son.”

But “ our opinions are not in our own power, they a formed and governed much by circumstances that are often inexplicable as they are irresistible.” He considered his s might have remained neutral in the struggle, and not ha taken up arms against his father's countrymen, as there “ a natural duties which precede political ones, and cannot extinguished by them.”

Though he was seventy-nine years old, and departing fro Europe gloriously, he was not distracted from work duri the voyage by the multitudes of memories that must have ris in his mind, as he watched the ocean.

He wrote long descriptions of various scientific matte which he had not been able to describe before, owing to la of time.

He described a boat he had seen on the Seine, driven b air-screws turned by hand.

He made the first scientific study of the Gulf Stream, wit numerous measurements of the temperature of the water.

“ This stream is probably generated by the great accumul tion of water on the eastern coast of America between th tropics, by the trade winds.

“ I find that it is always warmer than the sea on each sid of it, and that it does not sparkle at night.” The difference of temperature were about 6° F.–10° F. and the water wa frequently warmer than the air above.

He suggests that it warms the air above, and forms “ thos tornados and waterspouts frequently met with and seen nea the stream.” The condensation of the moisture in this warm air by the cold water of Newfoundland produces the fog there. The drift of the stream is sufficient to retard a sailin vessel sixty or seventy miles in a day. Franklin drew a char of the stream from information supplied him by America sea captains. The temperature of water at various depths wa obtained by letting down corked bottles. At thirty-five fathoms the cork was stove in by the water pressure. When hauled to the surface the temperature of the water in the bottl was 6° F. lower than that of the surface water.

He records more of his ideas on fireplaces and ventilation He complains that architects “ have no other ideas of proportion in the opening of a chimney than what relates to symmetry and beauty, respecting the dimensions of the room, while its true proportion, respecting its function and utility, depends on quite other principles; and they might as properly proportion the step in a stair-case to the height of a story instead of the natural elevation of men's legs in mounting."

This contains the statement of the principle of modern functionalist architecture. "In time, perhaps, that which is fittest in the nature of things may come to be thought handsomest." "Some, I know," are "so bigoted to the fancy of a large, noble opening, that rather than change it, they would submit to have damaged furniture, sore eyes, and skins almost smoked to bacon."

Franklin was opposed to the abolition of capitals for nouns in printing. He considers it less easy to understand the meaning of passages without capitals. The modern functionalist printers do not use capitals, so he would not have been in agreement with them on that point. He disliked grey printing and preferred black.

He describes experimental models by which the ventilation of buildings could be investigated.

He suggests that mines could be ventilated by tall chimneys, which commonly produce vertical draughts through temperature differences between the walls and the air inside. If the chimney be painted black it will absorb more heat from the sun's rays, and hence produce more draught.

His physical infirmity prompted him to invent an instrument for lifting books off high shelves in his library. This consisted of two thin laths on the end of a stick. The laths could be inserted round the desired book, and then clapped tight by a string.

In 1787 Franklin, who had introduced Tom Paine to America, gave him an introduction to Rochefoucauld, asking him to assist the development of Paine's invention of the iron bridge. The pamphleteer was the first to suggest that bridges should be built of iron, and made a model to illustrate his idea.

Franklin was in favour of free-trade, but considered direct taxes impracticable in a sparsely populated country. He agreed in 1787 with his friend Morellet that "liberty of trading, cultivating, manufacturing, etc." is preferable "even to civil liberty, this being affected but rarely, the other every hour."

Franklin was elected a delegate to the Convention for the new Constitution. He was eighty-one years old, and had little influence on the deliberations. It is said that friendly guards

were set to watch him in company, and prevent him fro
giving away the Convention secrets.

He did not approve of the Constitution, but proposed th it should be signed unanimously, for the sake of unity. A cording to Jefferson, in his proposal of the general signatur Franklin said that it did not fully accord with his sentimen but he had lived long enough to have experienced that o should not rely too much on one's own judgment. He ha often found himself mistaken in his favourite ideas. H repeated that he materially objected to certain points, but the Constitution was the best possible under the circumstance it should go forth with united signatures.

He informed his French friend Veillard that he did n consider two chambers of representatives necessary. H hoped the Congress would soon improve the Constitutio He believed his countrymen "are *making experiments* in pol tics," as he wrote to Rochefoucauld.

His faculties waned in extreme old age. He was unable t perceive the genius of John Fitch, who built the first steam boat. Fitch's boat plied on the Delaware River in 178 Franklin saw it and described the sight in letters to friend But he would not subscribe for the continuation of Fitch experiments. When the inventor called on him, he was offere six dollars as a charitable gift, which was not to be accepted a a subscription for the boat. He declined the offer, and wa quietly infuriated. Fitch was unlettered and uncouth. Hi boat broke down, and he was considered crazy. He emigrate to Kentucky, and committed suicide near the Ohio River, afte having prophesied that some day the Ohio would be navigate by steamboats, and men more powerful than he would gai riches and fame from his invention.

Franklin's popularity declined with his powers. As h approached death, his acquaintances became fewer, and whe he died in 1790, the younger generation was not keenl moved. To them he appeared rather gross and grasping. H was not universally mourned. The French celebrated hi memory magnificently, and the United States House o Representatives observed official mourning, but the Senat did not.

III

SCIENCE AND THE AMERICAN CONSTITUTION

SCIENTIFIC ideas have had an exceptional influence on the history of America, more, perhaps, than on the history of any other country, except the U.S.S.R. The structure of the American Constitution has provided one of the channels for the exertion of this influence. At the present time, the Constitution is more than ever the centre of American political thought. The contentions between the executive, the houses of Congress, and the Supreme Court, affect the foundations of American life. If the form of the Constitution is partly due to the influence of certain scientific ideas, science has had a part in the rejection or delay, for good or ill, of social plans such as the New Deal.

As Franklin was the first great American scientist, and a member of the Convention that devised the Constitution, it is necessary to enquire whether the aspects of the Constitution which show the influence of certain scientific ideas were due to him.

In 1814 John Adams wrote a letter to John Taylor concerning the nature of different types of government. Taylor had inquired whether the differences between monarchy, aristocracy, and democracy were numerical or characteristic. Were they merely different ways of partitioning power among the members of the population, so that the one, or the few, or the many were sovereign ; or were they reflections of qualitative differences between the members of the population ? Did kings possess some higher quality not possessed by nobles, and did nobles possess some quality not possessed by the ordinary man ?

According to the first notion the differences between king, noble, and citizen are merely due to size. One governs because it has more power than the others. According to the second notion, one governs because it possesses power of a higher type, not merely more power than the others. It will be noticed that the first notion appeals to the ideas of arithmetic and mechanics, where one quantity is bigger or smaller than another, but not different in nature. Power in a system of government consisting of reactions between larger or smaller powers, all of the same nature, depends on the balance between the various powers. As Taylor wrote, it is " complicated with the idea of a balance."

The second notion involves characteristic differences between king, nobles, and citizens. For instance, the king may be supposed to be divine, while the others are not. He rules because he possesses a higher quality that places him above others, and gives him a higher order of wisdom. His power overcomes that of others not because it is merely larger, but because it is of a higher type.

The notion of the divine right of kings is derived from a dangerous extrapolation of biological observation. The differences between men and animals are very great, and appear to be qualitative ; to the primitive observer man seems to possess qualities fundamentally different from those of animals. Every man has been dependent on his parents or elders, and at an early age acquired an impression that they possess powers qualitatively superior to his own. The notion of divine right is derived from the belief in the qualitative differences between men, and between men and animals. It is interesting to note that Taylor illustrates the notion of king, nobles, and citizens as qualitatively different by a biological example : the characteristic differences between " the calyx, petal, and stamina of plants."

Taylor denounces both the mechanical and the biological notions of the system of government, and says that " they have never yet . . . been used to describe a government deduced from good moral principles."

Adams replied that the Constitution of the United States was certainly not deduced from good moral principles, but asks: " Is not the constitution of the United States ' complicated with the idea of a balance ' ? Is there a constitution upon record more complicated with balances than ours ? In the first place eighteen states and some territories are balanced against the national government, whether judiciously or injudiciously, I will not presume at present to conjecture. . . . In the second place, the house of representatives is balanced against the senate, and the senate against the house. In the third place, the executive authority is in some degree balanced against the legislative. In the fourth place, the judiciary power is balanced against the house, the senate, the executive power, and the state governments. In the fifth place, the senate is balanced against the president in all appointments to office, and in all treaties. This, in my opinion, is not merely a useless, but a very pernicious balance. In the sixth place, the people hold in their own hands the balance against their own representatives, by biennial, which I wish had been annual elections. In the seventh place, the legislatives of the several states are balanced against the senate by sextennial elections. In the eighth place, the electors are balanced against the people in the choice of the president. And here is a complication and refinement of balances, which, for any thing I recollect, is an invention of our own, and peculiar to us."

John Adams continues :

" However, all this complication of machinery, all those wheels within wheels, these *imperia* within *imperiis* have not been sufficient to satisfy the people. They have invented a balance to all balances in their caucuses. We have congressional caucuses, state caucuses, county caucuses, city caucuses, district caucuses, town caucuses, parish caucuses, and Sunday caucuses at church doors ; and in these aristocratical caucuses *elections are decided.*

" Do you not tremble, Mr. Taylor, with fear, that another balance to all these balances, an over balance of all 'moral liberty,' and to every moral principle and feeling, may soon be invented and introduced : I mean the balance of corruption ? Corruption ! Be not surprised, sir. If the spirit of party is corruption, have we not seen much of it already ? If the spirit of faction is corruption, have we seen none of that evil spirit ? If the spirit of banking is corruption . . . have you ever heard or read of any country in which this spirit prevailed to a greater degree than in this ? Are you informed of any aristocratical institution by which the property of the many is more manifestly sacrificed to the profit of the few ? "

Students of constitutional law, such as Woodrow Wilson and W. A. Robson, have cited this passage as an early exposition of the degree in which the notions of "checks and balances " entered into the structure of the Constitution.

Wilson writes that " the government of the United States was constructed upon the Whig theory of political dynamics, which was a sort of unconscious copy of the Newtonian theory of the universe. In our own day, whenever we discuss the structure or development of anything, whether in nature or society, we consciously or unconsciously follow Mr. Darwin, but before Mr. Darwin they followed Newton."

Wilson brilliantly argues that under Newtonian influence any system, including that of government, is conceived as a system of bodies moving according to the laws of mechanics and gravitation, in which action and reaction are equal an opposite, and all bodies are nicely poised by a balance of th forces acting on them. He writes that the Whigs tried to giv England a balanced constitution. They did not destroy th King, but offset his power by a system of checks and balances which would regulate his course, or at least make it calculable

Wilson considers that the English politicians, true to thei habits, did not clearly apprehend what they were doing, an the nature of their actions was first clearly explained by Montesquieu. He writes that " the admirable expositions of th *Federalist* read like thoughtful applications of Montesquie to the political needs and circumstances of America."

Wilson comments " that government is not a machine, but a living thing. It falls, not under the theory of the universe, but under the theory of organic life. It is accountable to Darwin, not to Newton." It should be subject to the laws of adaptation, and its organs should not be offset against each other, but co-operate quickly in the interests of life, and provide a " ready response to the commands of instinct or intelligence."

Wilson, like Taylor, invoked biological illustrations in contrast to the purely quantitative principles of the Whig theory of government.

Wilson's comments on the Newtonian characteristics of the Constitution are important and interesting, and exhibit an intellectual originality with which he has not commonly been credited.

There are also parallels between the " checks and balances" of the American Constitution, and the mental conflicts, or " checks and balances," in puritan psychology. The psychological frustrations of an Adams are related to the principles of the Constitution. It is significant that Franklin, who was free from complexes and frustrations, was philosophically opposed to the Constitution.

It is well known that the Constitution was devised by fifty-five statesmen, during four months' secret sessions of a special convention. Franklin was a member of the convention, though eighty-one years old. He expressed his opinion of the new Constitution in 1789, in a letter to a friend. He wrote that the provision of two houses, of representatives and senators, was a device for giving superior influence to the rich. He asked, " Is it supposed that widsom is the necessary concomitant of riches ? " " Private property is a creature of society, and is subject to the calls of that society, whenever its necessities shall require it, even to its last farthing." The payment of taxes does not confer a benefit on the public, but discharges a social obligation. "The combinations of civil society are not like those of a set of merchants," or board-meetings, in which the holder of the majority of shares decides policy. The important ends of civil society are personal securities and liberty, and the poorest has as much right to these as the richest. He regretted that there was a disposition to create an aristocracy of the rich.

He doubts whether the division of the English legislature into two or three branches was a product of wisdom, and suggests it arose from historical necessity, owing to the pre-existence of an odious feudal system. Notwithstanding its division of powers, the English Government had become an absolute monarchy, owing to bribery of the people's representatives by the king. He considered two houses defective in practice. A bad motion might be passed by one house because the persons who understood the matter best happened to be in the other house. This provoked contentions between the houses, which would never have arisen if all representatives had been in one house, so that those with special knowledge could have explained defects in the motion as soon as it had been proposed.

Franklin disagreed with the Constitution, but proposed that all delegates should sign it, as a better was not to be had, and he hoped it might soon be amended and improved by Congress. He thought that any form of government might serve, if operated by suitable men.

It is evident that the Newtonian notions of checks and balances, and mechanical equilibrium, were not introduced into the Constitution by Franklin, though he was a scientist. They were introduced by philosophic statesmen and lawyers who were not scientists. The incident provides an example of the dangers of the misapplication of scientific ideas by politicians who do not properly understand them. Mistakes of the same sort are occurring at present in various countries, where political oppression is excused by false biological theories of the nature of human beings. The most perfect statement of the principles which inspired the Constitution was made by James Madison in the tenth number of the *Federalist*. He wrote that "the diversity in the faculties of men, from which the rights of property originate, is not less an insuperable obstacle to a uniformity of interests. The protection of these faculties is the first object of government. From the protection of different and unequal faculties of acquiring property, the possession of different degrees and kinds of property immediately results; and from the influence of these on the sentiments and views of the prospective proprietors, ensues a division of the society into different interests and parties.

"The latent causes of faction are thus sown in the nature of man . . . but the most common and durable source of factions has been the various and unequal distribution of property. Those who hold and those who are without property have ever formed distinct interests in society. Those who are creditors, and those who are debtors, fall under a like discrimination. A landed interest, a manufacturing interest, a mercantile interest, a moneyed interest, with many lesser interests, grow up of necessity in civilized nations, and divide them into different classes, actuated by different sentiments and views. The regulation of these various and interfering interests forms the principal task of modern legislation, and involves the spirit of party and faction in the necessary and ordinary operations of the government."

Madison conceived the Constitution as a machine for the regulation of the various interfering interests. The struggles between the classes of society were to be nicely balanced by the machinery of the Constitution so that the wheels of society revolved for ever in an equilibrium comfortable to those who have the greatest faculty for acquiring property.

In view of Madison's explanation, it is astonishing to read in James Bryce's chapter on the Origin of the Constitution, in his book on *The American Commonwealth*, that among the creators of the Constitution "There were no questions between classes, no animosities against rank and wealth, for rank and wealth did not exist."

The chief engineer of the construction of the Constitutional machine was Alexander Hamilton, of coarser but more powerful genius than Madison. Hamilton passionately believed in the superiority of the rich and well-born. As Bertrand Russell has remarked, this belief may have been strengthened by reaction from the feeling of inferiority due to his illegitimate birth. Hamilton's belief appears to have been partly a psychological rationalization. He had much opportunity to become rich, but died poor. It seems that an unconscious motive of his action was not to become rich, but to receive the approbation of the rich and well-born, to achieve respectability.

A similar motive probably inspired the royalist sentiments of Franklin's son, and the aristocratic sentiments of his grandson, both of whom were illegitimate.

The complications of the checks, balances, and equilibria of the Constitution are an extreme form of the Whig theory of political dynamics. In some degree, they also are an expression of reaction against illegitimacy. The American revolutionaries were anxious to remove any appearances of loss of respectability produced by recent highly unrespectable activities. They sought to do this by adopting political theories which were an extension of orthodox British theories. In a sense, they were more royalist than the King. Some of the sources of the mechanical theories incorporated in the Constitution have been indicated by John Adams in his *Defence of the Constitutions.* His order of discussion of the subject-matter was influenced by that of Montesquieu in his *Spirit of Laws.* Montesquieu's book contains examples of Newtonian modes of thought, and was analysed by D'Alembert, the famous master of theoretical mechanics and author of D'Alembert's principle. In his section on Monarchy, Montesquieu writes :

" It is with this kind of government as with the system of the universe, in which there is a power that constantly repels all bodies from the centre, and the power of gravitation that attracts them to it. Honour sets all the parts of the body politic in motion, and by its very action connects them ; thus each individual advances the public good while he only thinks of promoting his own interest."

Adams quotes examples of the notion of balances from various authors. He gives passages from Machiavelli, where the possibility of the perpetual revolution of government through the forms of monarchy, aristocracy, and democracy is discussed. Machiavelli wished to discover how such " revolutions of infinity " may be prevented. He is appealing to the notion of stabilizing a machine. He wished to provide the social machine with an automatic speed regulator or governor. Adams' most interesting quotation is from Harrington : " empire follows the balance of property, whether lodged in one, a few, or many hands." In his *Oceana* he conceives the perfect government as an equilibrium between the king, nobility, and people, which cannot exist unless they are duly balanced against each other.

Adams discusses the views of various philosophers, including those of Franklin, on government. He assumes that Franklin was opposed to the notion of balances. In the Constitutional Convention Franklin had said that the notion of balancing two assemblies, such as a house of representatives and a senate, against each other reminded him of the practice of certain drivers of wagons drawn by four oxen. When they had a heavy load and came to a steep hill, they took a pair of oxen off, and chained them to the rear of the wagon, and drove them up hill, so that the rate of the descent of the wagon was moderated. Adams reprobated this oracular parable on balances, and proceeds: "The president of Pennsylvania might, upon such an occasion, have recollected one of Sir Isaac Newton's laws of motion, namely,—'that reaction must always be equal and contrary to action,' or there can never be any *rest*. He might have alluded to those angry assemblies in the heavens, which so often overspread the city of Philadelphia, fill the citizens with apprehension and terror, threatening to set the world on fire, merely because the powers within them are not sufficiently balanced."

Thus the lawyer Adams began to quote Newton against the scientist Franklin.

Several suggestive conclusions may be drawn from Adams' remarks. Adams and other American lawyers were fascinated by ideas supported by the authority of Newtonian mechanics. They, who were not scientists, were ready to brandish Newton's authority against their opponents.

Franklin, who was a scientist, was the only important member of the Constitutional Convention who was not impressed by conscious and unconscious appeals to Newtonian ideas.

Woodrow Wilson has made illuminating comments on the influence of Newtonian ideas on the formulation of the Constitution. But the notion of a constitution as a balanced mechanism is older than Newton. Machiavelli, who could conceive a constitution as a safety device, or speed regulation of social change, died in 1527. Harrington published *Oceana* in 1656. Newton did not publish the *Principia* until 1687.

The study of the American Constitution helps to show that "Newtonian" ideas are older than Newton. As Hessen has explained, Newton's mechanics grew out of the social movement named the Renaissance and Reformation. The chief feature of this movement was the development of trade, and the growth of the political power of the trading classes. As trade became more and more the basis of power, money and the production of goods became more and more important and interesting. The extension and refinement of production stimulated the study of the number and properties of goods. Improvements in the technique of arithmetic and physics, the sciences which describe the number and properties of things, followed. Some authorities state that the early Italian merchants introduced a symbol for zero into arithmetic. The merchants at first used a dot as the symbol of zero. Some of their slicker competitors swindled accounts by juggling with the dots, so large and unconcealable hexagons were introduced. The O is a degeneration of a quickly drawn hexagon.

With the progress of the Renaissance, men looked less and less to heaven and more and more to multiplication of money and goods as the source of power. The belief in government by divine right began to weaken. The respect for hieratic systems of qualities decayed. Before the Renaissance the intrinsic differences in quality between men, and between things, were considered the basis of understanding ; after the Renaissance, the quantitative differences were considered more important.

Galileo and Newton discovered their system of mechanics, because the progressive social thought of their time, that of the rising trading classes, already interpreted phenomena quantitatively rather than qualitatively. Newton refined and deepened a mode of thought already in existence, for example, in Harrington's theory of government. This is an important part of the explanation why Newton appeared in the seventeenth century, and not in the Dark Ages. Even his prodigious intellectual gifts would have been quite unable to work out the system of mechanics, if the general notions had not been implicit in contemporary thought. Newton was more indebted to society for the provision of a suitable intellectual background to his investigations, than society has been indebted to Newton for his brilliant extensions of an accepted mode of thought. The mechanics named Newtonian owe less to Newton than to the combined contributions of his predecessors, not only in the sphere of scientific thought, but in the sphere of general thought, and its characteristic attitudes towards the concept of nature.

Woodrow Wilson's diagnosis of the Constitution as Newtonian is only partly correct. He did not notice that Newton was inspired by a preceding system of ideas to which " balanced " and mechanical theories of government were related When Newton announced his laws of nature, he adopted the word " law " from contemporary theories of government, which were more or less consciously those of a mercantile society. Thus Newtonian mechanics is indebted to Whig or mercantile theories of government. In the environment of such theories, and allied systems of thought, he produced his mechanics. These, in turn, were adapted to give more precise expression to the theories of government suitable to trading classes. Thus there was a continual interaction between notions of government and scientific ideas.

The mutual interaction between the ideas in Newton's intellectual environment and his scientific thought was recognized by Macaulay. In a discussion of the state of England in 1685, he notices the remarkable work of the Royal Society in the application of science to practical affairs. Its members had given formal instructions to farmers on the best methods of planting, and had done much work on the production of new vegetables, the use of new manures, and the adaptation of foreign plants to cultivation in England.

The wide interest in experiment and theory provided an atmosphere in which the intellect of a Newton might flourish. Macaulay writes that

"Perhaps in the days of Scotists and Thomists even his intellect might have run to waste, as many intellects ran to waste which were inferior only to his. Happily the spirit of the age in which his lot was cast, gave the right direction to his mind ; and his mind reacted with tenfold force on the spirit of the age."

The influence of Utilitarianism on Macaulay is emphasized in this passage by his repetition of the phrase "running to waste," and his implied dismissal of the work of the Schoolmen as worthless. His suggestion that Newton had ten times as much influence on the spirit of the age as that spirit had on him is an exaggeration, but also an admission that Newton's intellectual achievements were an offspring of the culture which existed when he was born. He bred and polished the rough ideas which he found in a favourable environment, until they acquired a far grander appearance and power, though their nature still remained the same.

The influence on political thought of the system of ideas extended and refined by Newton has been discussed by Carl Becker in his study of the Declaration of Independence.

The political philosophies to which the Declaration of Independence and the Constitution appeal for justification are not the same, but nevertheless have many common features. They were derived from a system of ideas which had acquired wide prestige during the eighteenth century. Some parts of this system are invoked with particular emphasis and clarity in the Declaration.

The first paragraph states that a people may be entitled to independence by " the laws of nature and of nature's God." The second paragraph begins with the statement that " We hold these truths to be self-evident, That all men are created equal, that they are endowed by their creator with certain unalienable rights . . ."

These statements express very definitely the political philosophy of the natural rights of man.

This philosophy was the intellectual weapon used by those who achieved the independence of the United States, and it was as important as any other weapon used in the struggle. A complete explanation of why the United States succeeded in gaining independence cannot be given without counting the help received from the philosophy of the natural rights of man. Why did this philosophy have such strength and prestige in the last quarter of the eighteenth century?

A general tendency to research and exploration had been a feature of the human movement of the Renaissance. Men visited distant countries, examined the Bible, and made innumerable other investigations, and obtained interesting results which could be adapted to their own advantage. The activity of investigation was gradually systematized, and in some countries had begun to acquire the form of science. Investigation acquired prestige because it had brought riches and religious independence to many men. Success helped to create in men a deep respect for an activity which brought so much. As ships were the means of investigation in foreign trade, and continents were the source of interesting finds, so the reason was the means of investigation in intellectual affairs, and nature was the source of interesting finds. With the success of investigation, the prestige of reason and nature rose, and constituted Macaulay's " spirit of the age." Their prestige was considerable when Newton began to study, but it was greatly increased by his marvellously successful use of the concepts of reason and nature.

According to Thomas Aquinas the highest law was the Eternal Law, which was equivalent to God's mind. A portion of the Eternal Law was revealed to man through the Bible and the Church, and a further portion was accessible through the application of reason. This was natural law. Aquinas believed that the natural law accessible to reason was only a small portion of the Eternal Law. During the five hundred years following his time, more and more scope was ascribed to natural law, until, in the eighteenth century, as Becker explains, the scope of natural law was believed to cover the whole of the Eternal Law. The belief that the whole of God's mind was accessible to human reason became widely accepted. This was due to the success of the movement of which Copernicus, Galileo, and Newton were leaders.

The scientists reasoned with nature, and were rewarded with remarkable answers. They therefore paid more and more respect to nature, and began to deify it, and to neglect the Bible and the Church. This did not imply that they had become irreligious. The majority of scientists were religious, and Newton was extremely religious, but they had changed their tenets.

The spectacular explanation of the laws of the solar system by Newton immensely enhanced the prestige of nature as a source of knowledge. Before his work, the belief that the natural laws which govern the behaviour of objects on the surface of the earth, should also operate on the moon, and throughout all space, would have seemed impudently presumptive. The proof that this presumption was correct gave a correspondingly large encouragement to human confidence in the power of reason, and the importance of the information which nature might reveal.

Newton's spectacular results attracted attention from all men of broad interests, besides specialists. Voltaire was one of the first who expounded Newton's results to the general audience. John Locke began to study earnestly the wider implications of Newton's methods, after he had been assured by Huygens that Newton's mathematics was correct.

Becker quotes Gray's bibliography of Newton, which records that before 1789 forty books about the *Principia* were published in English, seventeen in French, three in German, eleven in Latin, one in Portuguese, and one in Italian.

Desagulier translated a popular exposition of Newton which passed through six editions by 1747, and published in 1728 *The Newtonian System of the World the Best Model of Government, an Allegorical Poem.* Here the influence of Newtonian science on political theory is already explicit.

A weightier exposition of Newtonian science was published by the very able Scottish mathematician, Colin Maclaurin, the author of the celebrated theorem named after him.

He explains that science satisfies man's curiosity about nature, provides improvements in technique, and pleases his aesthetic feeling. But it is "subservient to purposes of a higher kind, and is chiefly to be valued as it lays a sure foundation for Natural Religion and Moral philosophy; by leading us, in a satisfactory manner, to the knowledge of the Author and Governor of the Universe."

He believed that the student would learn to admire the beauty of the "Exquisite structure and just motions" of the system of nature, and would be "Excited and animated to correspond with the general harmony of Nature."

The introduction into political philosophy of the attitudes of Newtonian scientific thought was due especially to John Locke. The natural rights philosophy of the Declaration of Independence was acquired by Thomas Jefferson largely from Locke. In the Declaration the principle of that philosophy is invoked, when it is asserted that the rights of man exist in nature, and may be ascertained from nature by the exercise of reason.

This philosophical attitude is not so prominent in the Constitution, but more use is made of methods derived from it. The notion of mechanical equilibrium developed by Newton had the same origin as the philosophy of natural rights; both were derived from the investigation of nature by reason.

The American Constitution is a product of several centuries of such interactions, and is consequently a highly developed and refined expression of a system of thought concerning government and nature which dominated those centuries.

The presence of Newtonian ideas in the Constitution was due partly to their authority, and partly to the operation of the same social forces that had brought Newtonian ideas themselves into existence. The dominant American political thinkers, such as John Adams, were fascinated by Newtonian ideas. This shows that these ideas were peculiarly sympathetic to their modes of thought. If a discussion of the representative views of Adams reveals the influence of Newton, may not a study of the ideas of Adams be used to reveal peculiarities in Newton's ideas? May not the sympathy between their modes of thought be used to analyse Newton's thought?

In his article on Franklin in the *Boston Patriot* in 1811, Adams referred to Newton as "perhaps the greatest man that ever lived." Why did Adams, who was a lawyer, and did not understand mathematical astronomy, have such awe of Newton? Probably because he conceived Newton as the lawgiver to the universe. He was impressed, not by the difficulty of the scientific problems solved by Newton, but by the astonishing scope of the application of his results. Newton with pencil and paper worked out the Constitution of the Universe. This appealed to lawyers who desired to work ou the Constitution of the United States of America with pen and paper.

Adams was not particularly interested or impressed by Newton's contributions to experimental science. Those seemed fiddling compared with the legislation of the cosmos The legalistic aspect of Newton's work appealed to Adams This was to be expected. The immense fame of Newton, as Adams wrote, was connected with " mysterious wonder " a his achievement. A large part of his fame was due to the old-fashioned pre-Renaissance, scholastic modes of thought which Macaulay so much despised. He was regarded by many as a magician. He could predict the course of the stars, apparently by pencil and paper, and without other assistance This appealed to the demand of the unsophisticated for magic, and to the snobbery of the governing and leisured classes, who like to be able to exert power, without appearing to work. Similar motions help to explain the vogue of certain contemporary writers, such as Jeans, whose sweeping style seems, with ease, to give laws to the cosmos. His conceptions are characteristically Newtonian.

Newton's attitude and work are not entirely attractive to the twentieth-century mind, in spite of their prodigious nature. May this be due to the legalistic, scholastic qualities in his thought, which appealed to lawyers such as Adams, and are made doubly clear by the lawyer's admiration and approbation ? May the slight contemporary distaste for Newton be a reflection of the modern scientists' sympathy for the contradictions of the quantum theory, and dislike of legalism ?

The problem seems to become clearer from the study of the nature of Franklin's scientific work. Franklin was the most important scientist of the eighteenth century. He contributed more than any other scientist towards the establishment of the modern ideas of experimental science, and of advancing the condition of human society by experimental investigation. His greatest contribution was philosophical. He assisted the escape from the legalistic tradition that saturated the part of Newton's scientific work which received the widest public recognition, and exerted the greatest public influence.

The deepest importance of Franklin's achievement was in a large degree perceived by some of his greatest contemporaries. Joseph Priestley was directly inspired by contact with Franklin's emancipated mind. He describes how he had never thought of making discoveries by experiment until after he had met Franklin. Priestley, like Faraday, was interested in science for many years before he had the courage to believe that he might discover something new. He had thought of writing a history of electricity, and asked Franklin for advice. Franklin was very helpful and encouraging, and Priestley's career as discoverer grew out of the testing of the experiments described in the history. Priestley also records that his experiments on the properties of gases began to progress after a visit from Franklin. These experiments culminated in the discovery of oxygen, a tremendous contribution to the creation of modern science. Priestley's mind was fixed in theological habits of thought, in some ways like Newton's. Franklin emancipated him, and showed him the way to modern experimental science. He owed to Franklin the philosophical perspective that led him to his great achievements.

Priestley was aware that Franklin's work and attitude might be an advance on Newton's. He writes in the preface to his *History of Electricity* : " Hitherto philosophy has been chiefly conversant about the more sensible properties of bodies. Electricity together with chemistry and the doctrine of light and colours, seems to be giving us an inlet into their internal structure, on which all their sensible properties depend. By pursuing this new light, therefore, the bounds of natural science may possibly be extended beyond what we can now form an idea of. New worlds may open to our view, and the glory of the great Sir Isaac Newton himself, and all his contemporaries, be eclipsed by a new set of philosophers, in quite a new field of speculation. Could that great man revisit the earth, and view the experiments of the present race of electricians, he would be no less amazed than Roger Bacon or Sir Francis would have been at his. The electric shock itself, if it be considered attentively, will appear almost as surprising as any discovery that he made."

This passage shows that Priestley foresaw that experimental physics would become at least as important as mathematical astronomy. He was inspired to this vision by Franklin.

One of the reasons why Franklin had little influence on the construction of the American Constitution is now clear. The makers of the Constitution were lawyers who believed they were including in their work the supposedly imperishable ideas of Newtonian mechanics, which they did not understand. They distrusted Franklin partly because he felt he was not Newtonian. They never dreamt that he was the most confident pioneer of the next advance of science beyond Newton. Franklin was the forerunner of modern experimental scientists. He could not sympathize with lawyers in love with a scientific point of view already old-fashioned. He even tried optimistically to believe that the American statesmen were, like himself, experimentalists.

In 1788 he wrote to Rochefoucauld that " We are *making experiments* in politics ; what knowledge we shall gain by them will be more certain, though perhaps we may hazard too much in *that* mode of acquiring it."

The attitude of Adams and the others was profoundly different. They had no confidence in *experiments.* Adams wrote that political experiments unfortunately could not be tried in a laboratory before being tried on the community. He implied that political experiments were, for this reason, to be avoided. They were afraid of the dangers of the popular liberties necessary for political experiments. They desired only to design and construct as quickly as possible a complicated machine, in which the people could be safely confined. The machine was to be equipped with a system of automatic governors, safety-valves, and balance-weights, so that when the temperature of the confined people rose, their energy would be harmlessly discharged through a temporary acceleration of the balanced mechanism, and the original relative positions of the interacting parts, or social interests or classes, would remain constant for ever.

Parton has remarked that Franklin and Adams were the spiritual fathers of the Democratic and the Republican parties. Political experimentalism, of a sort with which Franklin might have sympathized, has recently become prominent in American affairs.

This belief in political experiment seems to be particularly strong in America.

In the past, politicians have asked for power on the ground that they alone knew how to solve all social problems, and only needed power to carry out the solutions. They regarded their assertion of omniscience as essential to political prestige. A new attitude has begun to appear in America, where leaders have plainly said that they did not know beforehand the solutions to all problems, but merely wished to have power to try various experimental policies.

This valuable American belief in political experimentalism is due in part to the influence of science and of the broad teaching of science, which is such an excellent feature of American education.

Franklin could not support the makers of the Constitution because, among other reasons, their philosophy involved scientific ideas already getting out of date.

The Senate did not mourn him after he died, and the States' debts to him were left unpaid. His reputation in America declined during the next century. He was remembered as a diplomat and a philosophical Sancho Panza whose overwhelming fascination was rather incomprehensible.

BIBLIOGRAPHY

The Complete Works of Benjamin Franklin. Compiled and edited by John Bigelow. 10 volumes. 1887 & cont.

The Writings of Benjamin Franklin. Collected and edited with a Life and Introduction by H. A. Smyth. 10 volumes. 1905 & cont.

Benjamin Franklin: Bourgeois d'Amérique. Bernard Faÿ. 1929.

Life and Times of Benjamin Franklin. James Parton. 2 volumes. 1892.

The Franklin Bicentennial Celebration. Philadelphia. Volume I. 1906.

Benjamin Franklin: The First Civilized American. Phillips Russell. 1927.

History of Electricity. Joseph Priestley. Fourth Edition.

Collected Works. Joseph Priestley.

The Spectator.

JOSEPH HENRY

1797–1878

JOSEPH HENRY

A Few Years over the Age of Thirty

I

THE SIGNIFICANCE OF HIS CAREER

JOSEPH HENRY was born in 1797 and died in 1878. He was descended from Scottish Puritans, and acquired from them a Calvinistic mode of thought. He grew up in a period when the civilization of the United States was still predominantly agricultural. He lived near Albany, which was a centre of state administration, and where the owners of large estates still had the most powerful voice in government.

Vigorous remnants of the stratified type of social structure appropriate to a landed aristocracy existed about Albany in Henry's youth. In such a structure there are elements of the caste system ; it is supposed that every person is destined to some particular status in which he will remain all his life. Henry was a tutor to the family of the patroon Van Rensselaer, a position equivalent to that of a clerk or scholar in medieval feudalism. He never left the scholar caste.

The influence of these circumstances was increased by the feebleness of his father, who was unable to earn a satisfactory living, and died when Henry was a child. The influence of his mother was enhanced by this event. She impressed her religious principles into him exceptionally deeply.

Joseph Henry was tall, handsome, and magnificently healthy. He was engaged in strenuous and successful research when he was eighty years old. He showed the extraordinary physical vitality of many Americans of his day. His nature was gentle and sincere, but his Calvinistic views were harder and more sombre than his temperament. In spite of his kind disposition, he had the fear of evil and consciousness of the frailty of man, which was characteristic of his co-religionists. As a scholar imbued with the ideas of caste or class, in an aristocratic agricultural civilization, he was far more interested in establishing his prestige in the scholar-class than in making money. This attitude, reinforced by his mother's theology, which emphasized the danger of damnation through riches, made him not indifferent to, but fearful of, money.

Henry received the small salary of $3,500 for directing the Smithsonian Institution, and refused, during thirty-two years, to accept an increase. As he was in Washington, he was regularly consulted by the Government on scientific questions. This involved much extra work, and the connection lasted for more than three decades, but Henry refused to accept any payment. He refused to accept payment for scientific advice to the Government during the Civil War. He refused to accept several university chairs with salaries much larger than that he received from the Smithsonian Institution, and which offered him far more free time for personal scientific research. For instance, he refused the chair of chemistry in the Medical School at the University of Pennsylvania " especially because . . . it might be supposed that he was influenced by pecuniary reasons."

Henry was the first to elucidate the principles of the design of electro-magnets. He was the first to employ electro-magnets in a successful electrical telegraph system, and the first to construct a reciprocating machine driven by direct electric current. These inventions were fundamental to the development of the electric telegraph and electrical machinery, but he refused to patent them.

They were employed by Morse in his development of the electric telegraph. As is often the case, success persuaded Morse and his financial backers to assert that their predecessor had exaggerated the importance of his unpatented contributions. Henry remarked in his reply to these assertions that : " My life has been principally devoted to science and my investigations in different branches of physics have given me some reputation in the line of original discovery. I have sought however no patent for inventions and solicited no remuneration for my labours, but have freely given their results to the world ; expecting only in return to enjoy the consciousness of having added by my investigations to the sum of human knowledge. The only reward I ever expected was the consciousness of advancing science, the pleasure of discovering new truths, and the scientific reputation to which these labours would entitle me."

Henry would " sell to no man, nor would he deny or delay to any man the precious knowledge drawn under the providence of God from the arcana of nature."

In 1865, when the Civil War had ended, he was sixty-eight years old, and established in Washington in a position of unique scientific distinction. He steadily followed his principles of conduct through the years of wild speculation which occurred before his death in 1878. His attitude to money was the exact antithesis of that of the majority of his later contemporaries. He remained loyal to the ethics of the scholar-class, and never modified his attitude as the prestige of the financial and capitalist classes increased.

He was forty-nine years old when he accepted the invitation to become the first Secretary, or Director, of the Smithsonian Institution. He interpreted his new studies as implying a cessation of personal research, and for the long remainder of his life he was firstly an administrator of scientific work. Under his direction, the Smithsonian Institution acquired a unique position and reputation in the encouragement of research and the popularization of science. It became the parent of the modern system of meteorological forecasting by telegraph, of the United States National Museum, the Bureau of American Ethnology, the National Zoological Park, the National Gallery of Art, of marine biological research stations such as Woods Hole, of a world system of exchange of scientific books and specimens between research workers, and many other first-class innovations.

During his secretaryship Henry considered he could not give time to personal research, but he gave much time to unpaid research for the Government. All of this research was of direct economic and social value. He made first-class investigations into the acoustics of the atmosphere in connection with the fog-signal system for protecting shipping, and equally excellent researches on meteorology, the strength of building materials, ballistics, solar physics, and other subjects.

This is an immense list of achievements, but it does not include his greatest researches. These were done in the years about 1830, when he discovered electro-magnetic self-induction before Faraday, and probably also discovered electro-magnetic induction before Faraday, but did not publish it first.

In total achievement Henry was the equal of Faraday, Helmholtz, Kelvin, Maxwell, and the other great scientists of the nineteenth century. He did not discover so many important new facts and theories as Faraday, but he contributed vastly more to the organization of scientific research. As G. B. Goode has explained, Henry " did much toward establishing the profession of scientific administration—a profession which in the complexity of modern civilization is becoming more and more essential to scientific progress." This is an important remark. The creation of methods of organization is even more urgent, in the conditions of modern civilization, than the discovery of such a profound phenomenon as electro-magnetic induction. Society is being disrupted by the scientific forces which have been released within it.

The most important contributions that may be made to modern culture are discoveries of rational methods of promoting and utilizing science. Henry was a distinguished forerunner of the modern social planners, who wish to integrate science into the machinery of society.

A study of Henry's achievements shows that he was a truly great man. But an air of disappointment has always hovered around his name. His friends and countrymen regretted that though he probably discovered electro-magnetic induction before Faraday, he failed to publish it first. There is a wide opinion that if Henry had made this discovery exclusively American, he would have contributed more to the advancement of science in America by this single achievement, than by the manifold contributions that he recognizedly made. He would have given American science an inspiration which might have enabled it to dominate nineteenth-century physics. This, in turn, would have raised the standard of the whole of American culture, and have made American spiritual achievements in the period more equal to the material achievements. This argument appeals to the principle of individualist competition as the motive of progress.

Henry despised money, and the principle of competition. He despised competition in priority. He refused to gamble, even in research. This code of conduct was based on his religious and social ideas. It prevented him from making the intellectual gamble that might have won world leadership in electrical research for American physicists in 1831, and which might well have persisted.

Henry's social ideas belonged to a system in which the church would have ruled the state. They were closer to those of Calvin's theocracy at Geneva than of nineteenth-century capitalism, and have more in common with socialism than competitive individualism. By rejecting personal competition for fame and wealth, Henry rejected the principles which were beginning to dominate American life. He stood outside the main stream of the contemporary American spirit. He did not become assimilated to modern American individualism. This failure to enter into, and use, the dominating system of social ideas, helps to explain the atmosphere of effeteness and disappointment over his career and that of the Smithsonian Institution. His career, and the Institution, were great, but were not what the Americans of the day wanted. The great man who expressed their ideals in science, and whom they recognized as an indubitable genius, was Thomas Alva Edison.

In his memorial address of 1878 R. E. Withers surprised some by stating that Henry " was not a genius." This meant that his greatness was not of the Edison type. He probably believed that Henry's decision to cultivate broad interests was due to the lack of an overwhelming passion to follow a narrow or individual interest. He did not make any overwhelming contribution in any narrow direction. He refused to exploit his circumstances and employers in order to make discoveries. He was not, like Faraday, working continuously in isolation and never assisting the work of others, and he did not sacrifice his family and social life in order to pile a pyramid of discoveries. He was always refusing, and constraining himself. He showed the continuous inhibitions of Scottish caution. The extreme modesty of his claims to priority, and his praise of others who published before him, though they had discovered after him, show symptoms of what the modern psychologist calls masochism.

He considered that science did not have any necessary connection with the ordinary affairs of human life. That it might be useful to man was a happy accident, due to a benevolent Providence.

The majority of Americans did not sympathize with Henry's ideals and programme of work. He was not struggling for his own ends. He was in fact serving the interests of the proprietors of American industry and agriculture. He served the governing classes loyally, owing to his Calvinistic sense of duty, though his ideals were different from theirs. He did not conceive the government as the expression of certain dominant groups in the community. He thought it was above all particular interests, and for that reason, like God, should receive obedience., His lack of insight into the nature of the state explains why he could loyally serve classes with different ideals, and why leaders of those classes, whom he served so well, should fail to appreciate him adequately and perceive that he was a genius.

Henry disapproved of the idea that it is permissible for a scientist to make money out of his scientific discoveries, and yet the whole of his personal energies for research, after he became Secretary of the Smithsonian Institution, was devoted to investigations of economic importance. The economic needs of the state, of American agriculture, navigation, and industry, encouraged his researches in meteorology, fog-horn acoustics, ballistics, strength of building materials, etc. Problems are of interest to the state when dominant or powerful classes want to make, save, or get money out of them.

Henry saw no contradiction between refusing to make money for himself and agreeing to make money for a state dominated by the rich. While he refused to make money for himself, he did not object to being an instrument which increased the efficiency, and profitability, of agriculture and industry, by the application of science.

In the first part of his career he investigated the general problems to which post-Renaissance trade and industrial interests had directed human attention. He studied how to increase the efficiency of machinery, and how to elucidate its principles. The particular machines he studied were electromagnets. Thus, at first, Henry was an indirect instrument of the advance of the interests of industrialism. And still he believed that the motive for scientific research is divine curiosity, or the desire for insight into the " arcana of nature."

He followed his ideals with inflexible persistence in his great administration of the Smithsonian Institution.

The ideals which prompted James Smithson to found the Institution were profoundly different. Smithson was the bastard son of an English duke and a woman of royal descent. Owing to the circumstances of his birth, he was denied the full privileges of his father's class. He bequeathed the money for the foundation of the Institution from motives of revenge due to outraged class feeling. By that means, he wrote, " my name shall live in the memory of man when the titles of the Northumberlands and the Percys are extinct and forgotten."

His father, the Duke of Northumberland, disowned him, and yet his mother, descended from King Henry VII, was of even nobler blood. He hated his father, and his desire for eternal fame, more durable than that of the Northumberlands, was increased by the psychological complex, of which Oedipus offers the most famous example.

The spectacle of the great and earnest Henry, with his Puritanic sense of duty, carrying out Smithson's will with meticulous care, and creating with conscientious solidity, through thirty-two years, the firm foundation of Smithson's eternal fame, is one of the most interesting examples in the history of science of the interactions of different class motives and psychologies.

II

HIS LIFE AND WORK

THE grandparents of Joseph Henry were Scottish. They landed at New York on June 16th, 1775, the day before the battle of Bunker Hill. His grandfather had the surname Hendrie, but adopted the form Henry, perhaps because his new countrymen elided the dee-sound when they pronounced his name. Henry regretted that his grandfather had not preserved the Scottish form, as it was more distinctive. His grandmother was surnamed Alexander. The Henry family settled in Delaware County and the Alexander family in Saratoga. Joseph Henry's parents were living in Albany when he was born. They were poor, as his father, William Henry, worked as a day labourer. William Henry was apparently unable to give his family much support. When Joseph Henry was seven years old, an uncle, who was the twin-brother of his mother, sent him to Galway in Saratoga, where he lived with his maternal grandmother, and attended the district school. William Henry died about two years later, when Joseph was nine years old. Thus from the age of nine years Joseph Henry was a son of a widowed mother. This increased the degree of his mother's influence on his character. She was a small woman with delicate and beautiful features, and a refined temperament. She lived to a considerable age. She was a devout and strict member of the Scottish Presbyterian Church.

Joseph Henry agreed with the view that the character is formed before the age of seven years. His history shows that his mother had permanently impressed Presbyterian ideals in him. These were the foundation of his later behaviour and decisions, in so far as those depended on personal principles.

While his early religious training left the deepest impress, his early education did not proceed rapidly. He was not fond of school, and did not show special aptitude for learning.

His first taste for reading was stimulated accidentally. His pet rabbit ran into an opening under the village meeting-house. He crawled in pursuit through an opening in the foundation wall, and passed under the floor. He noticed light coming through a gap where the floor was broken. He was excited by the secrets of the room and decided to explore them. He climbed through the gap, and discovered an open case of books, which happened to form the village library. He picked out one, and began to read it, and was soon deeply interested. This was *The Fool of Quality*, by Henry Brooke. G. B. Goode says that Joseph Henry was about eight or ten years old when he discovered this book. The hero of the story is the despised younger son of a dissolute nobleman. The elder son was trained to the peerage, while the younger was deposited in the country with a farmer's wife as foster-mother. The effects of the different educations are the reverse of the intention. The elder son is ruined and the younger acquires sturdy virtues. Brooke works disquisitions on sociology, economics, and religion into the story. The education of the hero is according to the precepts of Rousseau, and the views on human labour as the source of wealth are drawn from William Petty and the mercantilists. Through the experiences of the hero, Brooke speaks against the oppression of the poor. His novel was published between 1766 and 1772. He was a forerunner of the nineteenth-century Liberals. He writes that poverty arises from ignorance, and not from laziness or incapacity. He attributes the misery of Ireland where he lived, to ignorance, and writes that in his time forty-nine out of fifty Irishmen were incapable of helping themselves because they did not know how. He compares the poverty of the English with the prosperity of the Dutch, and attributes the latter to knowledge of the technique of water transport. He recommends the construction of canals for increasing the prosperity of England. Ten years after Brooke published his novel the first English industrial canals were dug. Thus the neglected younger son, the Fool of Quality, left to a simple Rousseau-ean rearing, becomes the protagonist of progress. It is significant that such a book should have interested a boy of eight or ten years.

John Wesley admired Brooke's novel. Charles Kingsley wrote in 1859 that " he purged . . . such passages as were not to his mind, and then republished (it) during the author's lifetime, as the ' History of Harry, Earl of Moreland,' a plan which was so completely successful, that country Wesleyans still believe their great prophet to have been himself the author of the book."

Perhaps *The Fool of Quality* was put into the Galway meeting-house library by Methodists. The different educations of the elder and younger brothers are described in the opening pages.

"Richard, who was already entitled my little lord, was not permitted to breathe the rudeness of the wind. On his slightest indisposition, the whole house was in alarms; his passions had full scope in all their infant irregularities; his genius was put into a hotbed, by the warmth of applauses given to every flight of his opening fancy; and the whole family conspired, from the highest to the lowest, to the ruin of promising talents and a benevolent heart.

"Young Harry, on the other hand, had every member as well as feature exposed to all weathers; would run about, mother naked, for near an hour, in a frosty morning; was neither physicked into delicacy, nor flattered into pride; scarce felt the convenience, and much less understood the vanity of clothing; and was daily occupied in playing and wrestling with the pigs and two mongrel spaniels on the common; or in kissing, scratching or boxing with the children of the village."

Joseph Henry's interesting opinions on education will be explained presently. It is possible that they were influenced by Brooke. It is possible that, as a widow's child, he sympathized with the younger son in the story, who was virtually without a father. As he played with pet rabbits, he would appreciate wrestling with spaniels. He must have read the book about 1805 or 1807. This was during the period of the ascendancy of Thomas Jefferson. Henry's mind was formed when the ideal of an agricultural society was dominant. It never lost that mark.

Henry regarded *The Fool of Quality* purely as fiction. It stimulated his taste for more. He repeatedly returned through the hole in the floor to the village library, and presently was allowed access through the usual door. He read the whole of the stock of fiction.

At the age of ten he worked as an office-boy in the local store of a Mr. Broderick. He was kindly treated, and allowed to attend school during the afternoons. Broderick's store was the centre of village gossip and popular discussion. Henry used to lounge around the store, listening to passing affairs, and recounting to other boys the stories he had lately read. He was tall for his age, thin, delicate, and impulsively enthusiastic.

He left Galway when he was about fifteen years old, and returned to his mother in Albany, where he was apprenticed to a watchmaker and silversmith. After two years, the business failed, so he was released from his apprenticeship.

During these years Henry learned the use of accurate tools and manipulation, which assisted him afterwards when he became an experimental scientist. But his work with the watchmaker did not stimulate an interest in science or mechanics. His reading of fiction at Galway had still the chief possession of his mind. He was attracted by the theatre in Albany. Between the years 1813 and 1816 there was an unusually good theatre there under the management of a capable English comedian named John Bernard, whose company included several actors and actresses who became noted in America. Bernard was the author of a book on the stage, and on America, between the years 1797–1811.

Henry saw as many plays as possible, and succeeded in getting behind the scenes, where he learned how stage effects were produced. He joined or organized a juvenile debating and theatrical society named the Rostrum, of which he became president. As he was without employment he gave the whole of his time to dramatizing stories, writing comedies, and translating a French play. He produced these plays, with notable ingenious stage effects, and acted in them himself. As he was tall, handsome, lively and intelligent, it seemed that he might have become a successful professional actor. His early experience of the stage probably helped him to acquire his command of public speaking, and effective, charming and persuasive address. During the period of his pursuit of the theatre he had a slight accident, which kept him at home for a few days. He picked up a book which had been left on a table by a young Scotsman named Robert Boyle, who was lodging in the house. It was a collection of *Lectures on Experimental Philosophy, Astronomy and Chemistry, intended chiefly for the use of young persons*, by G. Gregory, D.D. The author was the Rector of West Ham, near London. He edited the works of the poet Thomas Chatterton, and compiled a dictionary of the sciences, besides many other books. He became Bishop of St. David's.

Boyle presented the little volume of lectures to Henry, when he observed his interest in it. The edition was published in 1808, so it was up-to-date.

Gregory discussed the scientific explanations of simple natural phenomena in a direct, conversational style. He writes : " You throw a stone, or shoot an arrow into the air ; why does it not go forward in the line or direction that you give it ? Why does it stop at a certain distance, and then return to you ? . . . On the contrary, why does smoke or flame always mount upward, though no force is used to send them in that direction? . . . Again, you look into a clear well of water and see your own face and figure, as if painted there. Why is this? You are told that it is done by reflection of light. But what is reflection of light?

The scientific attitude towards nature was new to Henry, and he was fascinated by it. He discovered that he could employ his imagination to investigate the mechanism of nature. When he saw that the investigation of natural phenomena provided more scope than drama for the exercise of an original imagination of a logical character, he retired from his dramatic society, after delivering a farewell address, in order to educate himself in science.

Henry wrote on a blank page of his copy of Gregory's *Lectures*:

"This book, although by no means a profound work, has, under Providence, exerted a remarkable influence on my life. It accidentally fell into my hands when I was about sixteen years old, and was the first book I ever read with attention. It opened to me a new world of thought and enjoyment; invested things before almost unnoticed with the highest interest; fixed my mind on the study of nature, and caused me to resolve at the time of reading it that I would immediately commence to devote my life to the acquisition of knowledge."

He became a pupil in the night school of the Albany Academy, and worked hard at geometry and mechanics. He was now a tall youth with a sinewy frame and strong constitution. He could work sixteen hours a day, continuously, for years, without serious fatigue. He had the Scottish intellectual characteristics of calm and clarity supported by determination, in an exceptional degree, but his early life had developed artistic qualities often neglected by Scots. His personality was more balanced than that of a native Scot.

As soon as he was able, he became a teacher in a country school, in order to save money for the cost of a fuller course at the Academy. He found that a knowledge of higher mathematics was necessary for the pursuit of science, so he resolutely learned the differential calculus.

When he had completed the academic course and passed the examinations, he was appointed tutor to the family of General Stephen Van Rensselaer, a landowner of Dutch descent, and president of the trustees of the Albany Academy. He was not expected to teach more than about three hours daily, so he had leisure for further study. He assisted Dr. Beck, the principal of the Academy, in chemical experiments, and attended courses on anatomy and physiology, with the intention of qualifying as a medical doctor. He read Lagrange's *Mechanique Analytique*. He was now receiving general encouragement, but his intense studies had impaired his health. He accepted an invitation secured through the influence of a friend, to act as engineer on a road-survey from West Point to Lake Erie. His health was restored by work in the open air, and he earned some money and much credit. He remained exceptionally healthy and vigorous for the remainder of his life. He had enjoyed the engineering, and had decided to accept the direction of the construction of a canal, when he was informed that he had been nominated for the chair of mathematics in the Albany Academy. He accepted this appointment in 1826.

He was now twenty-eight years old. He was expected to teach seven hours daily, including three and a half hours' arithmetic to a large class of boys. In his spare time he started the electrical researches which became famous.

Like many other cities at the end of the eighteenth century, Albany had a number of scientific societies. Two of these were amalgamated in 1824, to form the Albany Institute. Van Rensselaer was also the president of this organization. Scientific meetings were held in the Institute, lectures with demonstrations were given during the winter, and transactions were published. Dr. Beck's lectures on chemistry, like Humphry Davy's in London, attracted a fashionable, besides intelligent, audience.

Albany was the capital city of New York State. It was the headquarters of the state administration, and had an unusually large professional and educated population. This explains why it had a good theatre and several learned societies and institutes. It was a relatively admirable birthplace for a man of science, and Henry's scientific achievements were due in a considerable degree to the circumstance that he was born in one of the most cultivated American cities of his day. His opportunities at Albany might be compared with those of Davy at the Bristol Pneumatic Institution. Both were in provincial centres of learning. Davy had the advantage of meeting more talented men in his youth and at Bristol, before he went to the Royal Institution in London. Henry assisted Beck with the experiments, as Faraday assisted Davy. He found opportunities to make experiments of his own. His first communication to the Institute dealt with experiments on the cooling of steam by sudden, or adiabatic, expansion.

He held a thermometer in a jet of steam escaping from a boiler, and showed that as the temperature and pressure of the steam in the boiler was increased, the temperature registered by the thermometer decreased. Then he demonstrated that a jet of escaping steam will not scald the hand when exposed to it, if the original temperature of the steam is sufficiently high.

Henry's career as an experimental investigator began with research into problems that had been set by the development of the steam engine. The line of his work was determined by the growth of industrial technique.

His next paper was on the production of cold by the expansion of air. He put half a pint of water in a strong copper sphere of five gallons capacity. Air was pumped into the remaining space, up to a high pressure. The sphere and its contents were allowed to cool to room temperature, and then the air was suddenly released. The water inside the sphere was frozen. Henry remarks that " this experiment was exhibited to the Institute within six feet of a large stove, and in a room the temperature of which was not less than eighty degrees of Fahrenheit's thermometer."

These experiments did not reveal any new principles, but they showed that Henry had acquired an excellent command of experimenting, and had learnt how to describe results clearly.

He undertook the road survey after they were published, and was appointed to the chair of mathematics when he had completed the survey. The Albany Academy was one of the institutions supervised by the Regents of the University of the State of New York. In 1825 the Regents organized meteorological observations for the State, and instruments were set up in the Academy as part of the system. Henry and others were asked in 1827 to tabulate the observations. This began a long and distinguished connection with meteorology. The observers were expected to note the climatic conditions on days when any peculiar behaviour of plants and animals occurred. The influence of agricultural interests on the development of the science of meteorology is seen in this instruction.

Henry's first paper on electro-magnetism was read to the Institute on October 10th, 1827.

Simon Newcomb has remarked that no American since Franklin had made any contribution to the science of electricity, until Henry began his researches. This interregnum of seventy-five years was, in his opinion, one of the most curious features in the intellectual history of America. There had been " plenty of professors of eminent attainments who had amused themselves and instructed their pupils and the public by physical experiments," but they had not been inspired by Franklin's brilliant example to discover new knowledge of electricity. This is an important problem for the students of the history of science. Many factors contributed to the phenomenon. The absorption of American energy in pioneering and the achievement of independence, and the slow emancipation from the intellectual tutelage of Europe, are among them.

Henry explains his approach to electricity in his first paper. He remarks that although electro-magnetism is " one of the most interesting branches of human knowledge, and presenting at this time the most fruitful field for discovery," it is less understood in America than any other branch of science. The popular lecturers have not availed themselves of the " many interesting and novel experiments with which it can supply them," and little attention has been devoted to it in the " higher institutions of learning."

" A principal cause of this inattention to a subject offering so much to instruct and amuse is the difficulty and expense which formerly attended the experiments—a large galvanic battery, with instruments of very delicate workmanship, being thought indispensable."

Henry then explains that this difficulty had been removed by William Sturgeon of London, who had devised a set of instruments which would demonstrate the phenomena of electro-magnetism without requiring powerful sources of current. He achieved this by general improvements in design, and also by incorporation of his great invention, the electro-magnet, into his apparatus. Sturgeon described his electro-magnet in 1825. It was capable of supporting a weight of nine pounds. Within two years Henry was following his researches, on the other side of the Atlantic. He suggested that in those apparatuses in which electro-magnets could not be used, greater sensitivity could be obtained by using coils containing many wires, after the manner of Schweigger, in his invention of the galvanometer. Henry designed elegant improvements of apparatuses such as De la Rive's ring, for demonstrating the alignment of an electrical coil across the earth's magnetic field.

The spur of the entertainment motive is prominent in the work of Sturgeon, who tried, and miserably failed, to gain a living by demonstrating and teaching electricity. His extraordinary career has not been adequately studied, though Joule wrote a sympathetic short account of it. The same motive is seen, among others, in Henry's first paper : the improvement in the efficiency and power of apparatus in order especially to increase its entertainment value.

Nowadays the spur of this motive is seen in the subsidy of laboratories for research on the technique of photography, talking machines and films, television, etc.

The deflection of a magnetic needle by a wire carrying a current was reported by G. D. Romagnosi in 1802, but his observation was overlooked. H. C. Oersted rediscovered the phenomenon in 1819 and swiftly drew adequate attention to it. Schweigger increased the magnitude of the effect by using a coil of many turns instead of a single wire. His instrument could be used for measuring the strength of the current passing through the coil, and was named a galvanometer. Henry improved the effectiveness of Sturgeon's demonstration apparatus by the systematic introduction into the design of carefully-made coils containing many turns. Then he began the systematic improvement of Sturgeon's own invention of the electro-magnet.

Sturgeon's electro-magnet consisted of a bar of soft iron bent into a horse-shoe shape. The bar was varnished, and eighteen turns of bare copper wire wound round it. Large gaps were left between the turns, so that no electrical short-circuiting could occur. The design was very inefficient, but the magnet would support nine pounds weight when the ends of the coil were connected to a large-current battery. .

One evening, when Henry was sitting in his study with a friend, he arose and exclaimed after a few moments of reverie : "Tomorrow I shall make a famous experiment." He had just thought of a new way of winding electro-magnets, in the light of Ampère's theory of magnetism. "When this conception came into my brain I was so pleased with it that I could not help rising to my feet and giving it my hearty approbation." He began to construct electro-magnets in which the exciting coil was insulated, instead of the iron core. He used thin copper wire covered with silk. This enabled him to wind a very much larger number of turns around the core. Also, as the coils were very close, they lay almost at right angles to the axis of the core. This made the maximum use of the magnetizing force. In Sturgeon's electro-magnet the loose coils had a pitch, or lay across the core at an angle of about thirty degrees. Henry exhibited a horse-shoe electro-magnet in 1829 which contained 400 turns of silk-covered wire. The coil was wound over itself in successive layers. Thus he was the first to construct a magnetic spool, or bobbin. He found that this electro-magnet would support a considerable weight when excited by a small current.

Later in 1829 he exhibited an electro-magnet wound with several short coils instead of one long one. A half-inch iron bar was bent into a horse-shoe shape, and wound with thirty feet of tolerably fine copper wire. This bar would support 14 lb. when excited by a small voltaic battery. Henry then wound a second coil of 30 feet, and attached its ends to the same battery. He found the bar would now support 28 lb. With a larger battery, it would support 39 lb., or more than fifty times its own weight. He explained that his "experiment conclusively proved that a great development of magnetism could be effected by a very small galvanic element."

With P. Ten Eyck he investigated in 1830 how an electro-magnet behaved at the end of a wire 1,060 feet, or about one-fifth of a mile long. The wire was "stretched several times across the large room of the Academy." They secured two voltaic batteries. One consisted of a single pair of large plates, and the other of twenty-five pairs of small plates. The total area of zinc in both batteries was the same. They found that the electro-magnet would support 8 ounces, when the current from the twenty-five cell battery was sent to it through the 1,060 feet of wire. It lifted only half an ounce when similarly excited by the single-cell battery. He found that when the long wire was cut out of the circuit, and the electro-magnet connected directly to the twenty-five cell battery, the magnet lifted only 7 ounces. Henry comments on this remarkable result. He thinks it might have been due to variations in the conductivity of the battery, or to the slowing-down of the electricity in the long wire, which would enable it to go round the core more slowly when it arrived, and thus produce more magnetism in it. He would have verified the result by further experiments "had not our use of the room been limited, by its being required for public exercises." But he concludes that the coils of the magnet may either be single and long, or multiple and short; and the batteries must give a small current of high intensity, or a large current of low intensity, as circumstances require. An electro-magnet with a long single coil lifted less than when wound with several separate coils, but it had the property of being excited by a high-intensity battery through a long connecting wire. The current from a multiple-cell battery seemed to resemble that from a frictional machine. He points out that his results confirm the possibility of the construction of an electro-magnetic telegraph. Henry is therefore the inventor of the first telegraph employing electro-magnets.

Henry's experiments were made before Ohm's law had been recognized and units for voltage, amperage, and resistance had been defined.

P. Barlow had denied the possibility of the electro-magnetic telegraph, because experimenters had found that the current from low-voltage batteries did not produce sensible deflections in galvanometers at the ends of long connecting wires. As mentioned in Chapter I, electric communication through considerable distances had been achieved early in the eighteenth century with frictional electricity. W. B. Taylor remarks that Salva worked a static electric telegraph over a distance of 26 miles, between Madrid and Aranjuez, in 1798. This succeeded because the electricity produced by frictional machines is of a high-voltage, low-amperage type.

Henry and Ten Eyck proceeded to construct an electro-magnet, with an iron core which weighed 21 lb. The piece of iron to be attracted to the core, the lifter or armature, as he names it, weighed 7 lb.; 540 feet of copper bell wire were wound round the core, in nine coils each containing 60 feet. The ends of the separate coils were left projecting, and all numbered. " In this manner we formed an experimental magnet on a large scale, with which several combinations of wire could be made by merely uniting the different projecting ends."

The horse-shoe was suspended in a strong wooden frame 3 feet 9 inches high and 20 inches wide. The lifting power of various combinations of coils and batteries could be tested by hanging weights onto the armature. He found that two coils connected in series, when excited by a small battery, produced a lifting-power of 60 lb., but when connected in parallel, the lifting-power was 200 lb. Four coils in parallel gave a lifting-power of 500 lb., and nine gave 650 lb. The current from a voltaic battery, whose plates were exactly one inch square, was sufficient to produce a lifting-power of 85 lb. when connected to the nine coils in parallel. With a larger battery he obtained a lifting-power of 750 lb.

The existence of considerable quantities of copper bell wire in Albany in 1830 was an important condition of Henry's researches. It would be interesting to know why it was easily obtainable there, and how he obtained the money to buy it. Henry writes in his paper that Dr. L. C. Beck suggested they should use " cotton well waxed for silk thread, which in these investigations became a very considerable item of expense." Beck made a number of experiments with " iron bonnet-wire, which, being found in commerce already wound, might possibly be substituted in place of copper," but they failed, owing to what would now be described as the high resistance of the iron. The invention of less expensive methods of construction was an important feature of these researches.

Henry's improvement of the electro-magnet by systematic experiment and measurement shows the influence of industrial engineering methods on the development of physics. Some years later Joule started an investigation of the efficiency of the electro-magnetic engine, or form of electro-motor, which led to the modern conception of the conservation of energy. His first experiments, like Henry's, were directed to the improvement of the electro-magnet, and the work of both showed the influence of the spirit of the industrial engineer, who must design efficient machines in order to reduce the costs of production. When steam-power, or energy, became a market commodity, an accurate measure of it was demanded by commerce. This was the motive of the investigations which led to the saving of power and the understanding of the theory of efficiency and conservation.

An electro-magnet capable of lifting 2,065 lb., or about one ton, was constructed at Yale College under Henry's direction in 1831. A weight of 89 lb. could be held without dropping, when the poles were reversed, by reversing the current. The principle was afterwards employed in the neutral relay of quadruplex telegraphy, described in Chapter III.

Henry's methods of constructing magnetizing coils were adopted by Faraday in the apparatus with which he discovered electro-magnetic induction, and powerful electro-magnets of his type were essential in the discovery of the polarization of light by a magnetic field.

In July 1831, Henry described a method of producing reciprocating motion " by a power, which," he believes, " has never before been applied in mechanics—by magnetic attraction and repulsion." He constructed the first reciprocating electro-magnetic machine.

He suspended a bar electro-magnet horizontally by a pivot passing through its centre of gravity. The north poles of permanent magnets were fixed under each end. When the current was sent through the coil of the electro-magnet, the north pole of the electro-magnet repelled the north pole of the permanent magnet, while the opposite occurred at the other pair of poles. The current was reversed by arranging that the oscillating magnet should bear connecting wires which dipped in and out of the acid of voltaic batteries, with each oscillation. The electro-magnet oscillated at the rate of 75 vibrations per minute for more than one hour.

Henry remarks that " not much importance, however, is attached to the invention, since the article in its present state can only be considered a philosophical toy ; although in the progress of discovery and invention, it is not impossible that the same principle, or some modification of it on a more extended scale, may hereafter be applied to some useful purpose."

Henry soon saw that the power developed by his machine was indirectly drawn from the combustion of coal, and the machine would not supplant steam as a source of power. He did not expect it would have any application, except in circumstances where economy was of no importance.

While at Albany Henry began to construct a dynamo.

Henry slung more than a mile of wire around an upper room in the Academy in 1831. He sent a current from a multiple-cell battery through it to an electro-magnet which attracted the hammer of a bell. He demonstrated this apparatus to his classes, in order to prove that signals could be swiftly transmitted to a distance by electro-magnetism.

He was urged to patent these inventions, but refused, as he " did not then consider it compatible with the dignity of science to confine the benefits which might be derived from it to the exclusive use of any individual." In 1876 he wrote that perhaps this opinion had been too fastidious. Henry was not opposed to patent laws. He considered they provided the most equitable method of materially rewarding inventors, but he believed that patenting was beneath the dignity of a natural philosopher. W. B. Taylor remarks that if he had profited from his inventions he would have had more adequate means for extending his researches.

After Oersted had rediscovered that a wire bearing an electric current would deflect a magnetic needle, many investigators tried to discover the reverse effect, the production of an electric current in a wire through a medium of magnetism. Faraday was the first to publish a demonstration of the effect, and the experiment is usually considered his greatest single achievement. He obtained his first positive evidence of electro-magnetic induction in August, 1831, with the assistance of a ring electro-magnet whose magnetic strength had been increased by adopting Henry's system of winding with several separate coils. On September 24th he is confident that he has obtained a " distinct conversion of magnetism into electricity," and by November 4th he had confirmed his results by a variety of experiments.

During the last few years Henry had also been investigating how electricity might be obtained from magnetism. Soon after he read of Faraday's success, he wrote a description of his own researches, and published it in July, 1832.

In this paper he starts by recalling that the discoveries of Oersted, Arago, and Faraday had shown the intimate connection between electricity and magnetism, and that magnetic effects, such as the deflection of a needle, were easily obtained from an electric current. This had immediately suggested that electric currents ought to be easily obtainable from magnetism, but, " although the experiment has often been attempted, it has nearly as often failed." He then writes :

" It early occurred to me, that if galvanic magnets on my plan were substituted for ordinary magnets, in researches of this kind, more success might be expected. Besides their great power, these magnets possess other properties, which render them important instruments in the hands of the experimenter : their polarity can be instantaneously reversed, and their magnetism suddenly destroyed or called into full action, according as the occasion may require. With this view, I commenced, last August, the construction of a much larger galvanic magnet than, to my knowledge, had before been attempted, and also made preparations for a series of experiments with it on a large scale, in reference to the production of electricity from magnetism. I was, however, at that time accidentally interrupted in the prosecution of these experiments, and have not been able since to resume them, until within the last few weeks, and then on a much smaller scale than was at first intended. In the meantime, it has been announced in the 117th number of the *Library of Useful Knowledge*, that the result so much sought after has at length been found by Mr. Faraday of the Royal Institution. It states that he has established the general fact, that when a piece of metal is moved in any direction, in front of a magnetic pole, electric currents are developed in the metal, which pass in a direction at right angles to its own motion, and also that the application of this principle affords a complete and satisfactory explanation of the phenomena of magnetic rotation. No detail is given of the experiments, and it is somewhat surprising that results so interesting, and which certainly form a new era in the history of electricity and magnetism, should not have been more fully described before this time in some of the English publications; the only mention I have found of them is the following short account from the *Annals of Philosophy* for April. . . ."

Henry quotes the statement of Faraday's discovery that if two insulated wires are laid parallel to each other, a current starting in one will induce a current in the other, in the opposite direction. Also, if a magnet is passed in and out of a coil, a current will be induced in the coil, while the magnet is in motion. Henry continues:

"Before having any knowledge of the method given in the above account, I had succeeded in producing electrical effects in the following manner, which differs from that employed by Mr. Faraday, and which appears to me to develop some new and interesting facts."

He describes how he had wound thirty feet of copper wire, covered with elastic varnish, round the soft iron armature of the electro-magnet which could lift 700 lb. The ends of the wire were connected to a galvanometer. The coils of the electro-magnet were excited by suddenly immersing the plates of a voltaic battery, to which they were connected. Henry observed that the galvanometer needle was momentarily deflected at the instant of immersion. To his surprise, he found that a momentary deflection occurred, in the opposite direction, when the plates were suddenly lifted out of the battery and the exciting current cut off.

He found that a current of electricity is momentarily produced in a coil surrounding a piece of soft iron, whenever magnetism is induced in the iron, "and a current in the opposite direction occurs when the magnetic action ceases, and also that an instantaneous current in one or the other direction accompanies every change in the magnetic intensity of the iron."

Henry then writes that "since reading the account before given of Mr. Faraday's method," he has made some more experiments. One of these consisted of obtaining sparks from the coil round the soft iron armature, by holding its ends near together when the electro-magnet was excited. He remarks that he has been forestalled in this experiment, as he has learned that J. D. Forbes of Edinburgh published an account of a similar experiment in March, " my experiments being made during the last two weeks of June."

Henry mentions that he has made " several other experiments in relation to the same subject, but which more important duties will not permit me to verify in time for this paper. I may however mention one fact I have not seen noticed in any work, and which appears to me to belong to the same class of phenomena as those before described." He then publishes the great discovery of self-induction.

From any point of view, this was a wonderful paper. He gives in it the first publication of the discovery of self-induction, and forestalled Faraday's repetition of this discovery by two years. He gives an independent discovery of the derivation of electric sparks from a current induced in a coil. He gives an account of a demonstration of electro-magnetic induction made before he had any knowledge of the method given in the account of Faraday's researches in the *Annals of Philosophy*.

It would be extremely interesting to know exactly when he first made this last experiment. Did he make it before he read the account of Faraday's work in the note in the *Library of Useful Knowledge*? It is not entirely clear whether his remarks concerning the " method given in the above account " refer both to this note and to the account in the *Annals of Philosophy*.

The note was appended by Roget to his article on Electromagnetism. As it is not often quoted, it is given here in full :

" *Note*. Since the above was sent to the press, a paper, by Mr. Faraday, has been communicated to the Royal Society, disclosing a most important principle in electro-magnetism, of which, I regret, I can only give the following brief statement.

" By a numerous series of experiments, Mr. Faraday has established the general fact, that when a piece of metal is moved in any direction, either in front of a single magnetic pole, or between the opposite poles of a horse-shoe magnet, electrical currents are developed in the metal, which pass in a direction at right angles to that of its own motion. The application of this principle affords a complete and satisfactory explanation of the phenomenon observed by Arago, Herschel, Babbage, and others, where magnetic action appears to be developed by mere rotatory motion, and which have been erroneously ascribed to simple magnetic induction, and to the time supposed to be required for the progress of that induction.

The electro-magnet effect of the elective [*sic*] current induced in a conductor by a magnet pole, in consequence of their relative motion, is such as tends continually to diminish that relative motion ; that is, to bring the moving bodies into a state of relative rest : so that, if the one be made to revolve by an extraneous force, the other will tend to revolve with it, in the same direction, and with the same velocity."

Roget's article was signed Dec. 12th, 1831. Henry does not say when he first read the note. Perhaps it was about March, 1832.

Henry's paper of July, 1832, and the history of its contents, have been carefully analysed by his daughter Mary A. Henry, in six articles published in 1892. She writes that the experiments described in the paper are to be divided into two groups, those done before he had any knowledge of Faraday's method, and those done afterwards. She explains that those made "since reading the account . . . of Mr. Faraday's method" were done in the last two weeks of June, 1832. The experiments in the first group, which includes the great experiment with the coil wound round the armature of the electro-magnet, were done before Henry had read the April number of the *Annals of Philosophy*, which he may have received in May. Thus the experiments were done before May. (Miss Henry does not discuss the bearing of Roget's note, but Henry may have read this in March. In that case, according to Miss Henry, he would have made the experiments before March.)

Miss Henry now points out that it is extremely unlikely that Henry had any opportunity for experiments between August, 1831, and June, 1832. The Academy's hall, where he made experiments, was occupied by other activities during that period, and Henry himself was engaged in a vast amount of teaching and lecturing. Henry's own account in the July paper suggests that he had no opportunity for experiments between August, 1831, and June, 1832.

Thus Miss Henry concludes that Henry made his definitive experiment on electro-magnetic induction in August, 1831, or earlier. She explains that Henry had only one month's vacation in the year. He taught seven hours daily, largely to children, and he had no permanent room for experimenting. The America of 1830 was unable to provide a permanent room for the researches of a genius such as Henry. This illustrates the state of culture in the country at the time.

It was therefore probable that he made his chief experiments during the August vacations.

In August, 1831, he was constructing a new electro-magnet. Now Henry describes his definitive experiment as made with the old electro-magnet described in 1829. It seems probable, therefore, that he made his definitive experiments in August, 1830, while he was still working with his old magnet.

Miss Henry says that her father used to mention in private conversation that he had noticed sparks from the coils of his electric telegraph in 1829, and had suspected they were due to electro-magnetic induction. He said, also, that he had anticipated Faraday by about a year in the discovery, but unfortunately had not published an account of his researches, owing to the lack of time for the preparation of a thorough description of them.

A difficulty in accepting this last explanation is raised by Henry's comments in his July paper on the slowness of the publication of Faraday's researches. He says it is surprising that experiments which " form a new era in the history of electricity and magnetism, should not have been more fully described before this time in some of the English publications." If Henry himself was in possession of the result in 1830, and had been refraining from publication for two years, it seems odd that he should rebuke others for failing to publish a detailed description within a few months.

As a daughter, Miss Henry was in an excellent position to know Henry's private opinions, but her discussions were published in 1892, sixty years after the events. This diminishes the value of evidence she may have heard verbally many years before.

The question whether Henry or Faraday was the first in time to discover electro-magnetic induction seems not to admit an absolutely final answer. The probability is that Henry was the first. Certainly, he made a definitive experiment whose style was absolutely his own.

The comparison between the careers of Faraday and Henry as investigators of electricity up to the year 1835 is in Henry's favour. He lived in Albany in America, with little time, small resources, and few intellectual companions. Faraday lived in London, in a world-centre of intellectual activity, with much free time for research, and considerable resources. He was five years older.

Further, there were peculiar incidents in connection with several of Faraday's early electrical researches. Davy opposed his election to the Royal Society, on the ground that his work on electro-magnetic rotations was not original, and that the idea had been taken from Wollaston. Faraday was not generous in his recognition of Sturgeon, and he did not express his indebtedness to Henry for the technique of the design of electro-magnets very fully or exactly in his early papers. He failed to read Henry's description of self-induction in 1832. There is evidence that he was slower than Henry in recognizing the significance of experimental results in electricity.

Henry exhibits an almost morbid, or masochistic, modesty in the statement of his results and claims. He ascribes the minimum to himself, and the maximum to others.

A comparison of the early work of Henry and Faraday on electro-magnetic induction shows that Faraday has received too much praise for his contribution. Electro-magnetic induction was the least unique of his important discoveries. His greatness rests far more on his development of the idea of lines of force, and of the electro-magnetic field.

Henry never questioned Faraday's priority. No scientist has been more careful than he in matters of priority. His care did not arise from a contempt of applause, but from a desire not to receive applause for things he had not done. He considered the approbation of intellectual equals the greatest distinction in the gift of humanity, and he wished to preserve the standard of that approbation by the most exact assessment of achievement. Thus he disapproved of the slightest exaggeration of an achievement, and was inclined to ignore any claims concerning which there was vagueness or doubt.

From the perspective of the history of science, the question of personal priority is of no importance. The significant feature of Henry's great paper of July, 1832, is that the phenomenon of electro-magnetic induction was discovered, or about to be discovered, independently at about the same time in Albany, U.S.A., and in London, England. These events show that the progress of science depends far less than is generally believed on the efforts of individual geniuses. Faraday and Henry were the most advanced of a group of hundreds of investigators who assumed that if electric currents could produce magnets, then magnets should produce electric currents. The phenomenon of electro-magnetic induction is of enormous importance, but this does not necessarily imply that the experimental difficulties of discovery were very great. As Henry and Faraday made the discovery almost simultaneously, it could not have been of such a unique nature that it could occur only to one investigator of supreme genius.

Henry's achievements at Albany attracted the authorities of the College of New Jersey, or Princeton, and he was invited to occupy their chair of natural philosophy. He moved to Princeton at the end of 1832.

He had married his cousin Harriet L. Alexander in 1830. She had come to live in Albany after the death of her father, who had been a successful business man in Schenectady. They had ultimately six children, of which three daughters survived the death of their father in 1878. Mrs. Henry lived until 1882.

During the first years at Princeton Henry had little time for research. He had to organize his department and courses of lectures, and in 1833 fill in addition the chair of chemistry, mineralogy, and geology, whose occupant was spending a year's leave of absence in visiting Europe. He subsequently also lectured on astronomy and architecture.

While he was struggling with his pile of routine duties, Faraday was pursuing without interruption his investigations of electro-magnetism, and published his rediscovery of self-induction. Henry was urged by his friend A. D. Bache, the great-grandson of Benjamin Franklin, who was at that time professor of natural philosophy in the University of Pennsylvania, to write accounts of his further researches.

He constructed an electro-magnet which would lift one and a half tons, and showed for the first time how "a large amount of power might, by means of a relay magnet, be called into operation at the distance of many miles." He communicated by an electric telegraph from the College to his house, across the campus grounds. The wire was extended "from the upper story of the library building to the philosophical hall on the opposite side, the ends terminating in two wells." He used earth returns immediately after Steinheil in Germany had discovered their practicability.

He extended his researches on self-induction. A strip of copper 1½ inches wide and 96 feet long was insulated with silk and rolled into a flat spiral like a watch spring. He would have made a larger spiral, but could not obtain the necessary material. Sparks resembling discharges from a Leiden jar could be drawn from this coil.

Henry was given a year's leave of absence in 1837 to visit Europe. He was accompanied by A. D. Bache. He acquired the friendship of Faraday, Wheatstone, Arago, De la Rive, and other eminent scientists. He spoke to the British Association at Liverpool on the lateral electric discharge. He described experiments which confirmed Biot's opinion that it "is due only to the escape of the small quantity of redundant electricity which always exists on one or the other side of a jar, and not to the whole discharge."

Henry also spoke to the Mechanics and Engineering Section on the great development of railways and canals in the United States, and on the improvement of river steamers, some of which could steam at fifteen miles per hour. In the discussion Dr. Lardner, the economist, expressed doubts of the accuracy of Henry's statement concerning the speed of the American boats, and made his celebrated declaration, on the basis of observations on Thames steamboats, that oceanic steam navigation was impossible.

He visited King's College, London, to join Faraday, Wheatstone, and Daniell in an attempt to make a spark with current from a thermopile. The English experimenters tried it in turn and failed. Henry then attempted to increase the self-induction of the current by sending it through a long interpolar wire wrapped round a piece of soft iron. He succeeded in producing a spark. Faraday was delighted, and jumped up and shouted : "Hurrah for the Yankee experiment." Years later, Faraday and Wheatstone wrote a joint letter to the Royal Society, proposing that the Copley Medal should be awarded to Henry, but their proposal was deferred by the Council, and ultimately passed over. Mary A. Henry states that Wheatstone learned of the practical possibility of using a galvanometer for detecting a current at the end of a long telegraph wire from Henry during their London conversations in 1837.

After returning from Europe, Henry continued his researches on induction. He elucidated by experiment some of the properties of the transformer, demonstrating that currents of high voltage and low amperage could be obtained from those of low voltage and high amperage and the reverse. He proved this with a series of coils of various sizes. Pairs of coils were placed in contiguity, and the induction of currents in one from the other was examined.

He investigated the induction of currents in an exploring coil held in various places in the neighbourhood of the inducing coil. In this way, he discovered how the coils should be aligned in order to induce most effectively any desired type of current ; and the most effective dimensions, and design, of the coils.

He found that soft iron placed in a coil could be magnetized by induction from remarkably great distances. He found that induction could be made through the walls of a room. A person in an empty room, holding the ends of a coil, might be given a shock by a current induced from another coil in an adjoining room. Henry remarks that the uninitiated sometimes imagined such shocks, without apparent cause, were due to magic.

He applied the action of induction at a distance to the graduation of the treatment of a patient suffering from a partial paralysis of the nerves of the face. The inducing coil was suspended from a pulley, and could be raised or lowered over the coil in which current was induced, so that the strength of the induced current could be varied, to give shocks of the correct intensity.

He examined the screening effect of materials placed between two coils. He found that conductors destroyed the induction, but non-conductors did not. He proved that the screening effect of conductors was due to the induction in them of eddy currents which neutralized the current induced in the screened coil. This was done by cutting a slit in the metal screening disc. The slit disc had no screening effect. The direction the current would have taken in the complete disc was discovered by connecting the edges of the slit by wires to a detecting instrument.

Humphry Davy had found in 1821 that the magnetization of needles by electric discharges was unaffected by the interposition of screens, irrespective of whether they were made of conductors or non-conductors. Henry explained that this result was due to the disposition of his apparatus. He arranged the conductor screens in such a way that they were equivalent to the slit disc, and could not contain eddy currents, and therefore could not operate as electrical screens.

The fact that the primary current could be completely neutralized by a secondary current suggested to him that secondary currents could be separated from primary currents, and used to induce a current in a third conductor. In this way he established and investigated third, fourth, and fifth orders of induction.

He pointed out that the eddy currents induced in homogeneous conductors must reduce the efficiency of electro-magnetic machines. The rings of metal which formed the sides of the spools bearing the exciting coils would " circulate a closed current which will interfere with the intensity of the induction in the surrounding wire. I am inclined to believe that the increased effect observed by Sturgeon and Calland, when a bundle of wire is substituted for a solid piece of iron, is at least in part due to the interruption of these currents." Henry published this work in 1838.

He made a long series of experiments on induction by electric currents produced from frictional electricity. He found that induction by these currents had peculiar characteristics. Savary had observed in 1826 that a frictional electric discharge current magnetized needles with alternate direction of polarity, depending on their distance from the wire conducting the discharge, and had suggested that it was due to oscillations in the direction of the discharge. This phenomenon was thoroughly investigated by Henry. In 1842 he explained that it was due to a property of the discharge of a Leiden jar which had not previously been recognized. The discharge was not correctly represented by the single transfer of electricity from one side of the jar to the other, but to " the existence of a principal discharge in one direction, and then several reflex actions backward and forward, each more feeble than the preceding, until equilibrium is obtained." Henry definitely confirmed the theory that the Leiden jar discharge is oscillatory five years before Helmholtz expressed the same view in 1847, and Kelvin in 1852.

The currents induced by the oscillatory discharges were detected by the magnetization of needles put inside small coils. These detectors could be set up at any distance from the wire conducting the primary discharge. Henry discovered that the needles were magnetized when the detectors were placed at remarkably great distances from the discharge wire. He found that a single spark discharge in a parallelogram of copper wire sixty feet by thirty, suspended by silk threads in the upper room of a building, was sufficient to magnetize needles in an identical parallelogram in the cellar, thirty feet below, and separated by two floors and ceilings, each fourteen inches thick. Henry comments : " The author is disposed to adopt the hypothesis of an electrical *plenum*, and from the foregoing experiment it would appear that the transfer of a single spark is sufficient to disturb perceptibly the electricity of space throughout at least a cube of 400,000 feet of capacity ; and when it is considered that the magnetism of the needle is the result of the difference of two actions, it may be further inferred that the diffusion of motion in this case is almost comparable with that of a spark from a flint and steel in the case of light." Before commenting on this passage, two more experiments may be noted.

Henry connected one end of a coil in his study with the metal roofing on his house, and the other end to a metal plate in a deep well near the house. He found that needles put in this coil were strongly magnetized by lightning flashes which occurred " within a circle of at least twenty miles." He proposed to use this arrangement as " a simple self-registering electrometer for studying atmospheric electricity." He showed that the current produced in the house circuit by the distant lightning was oscillatory. He found that if a discharge from a battery of several Leiden jars was sent through the wire stretched across the campus in front of Nassau Hall, at Princeton, " an inductive effect was produced in a parallel wire, the ends of which terminated in the plates of metal in the ground in the back campus." The distance between the wires was several hundred feet, and the building of Nassau Hall stood in the intervening space. Henry remarked, in 1846, that it was concluded that the " distance might be indefinitely increased, provided the wires were lengthened in a corresponding ratio."

It is evident from these accounts that Henry was unconsciously detecting induction due to electro-magnetic waves. He had unwittingly invented the method of detecting radio waves which depends on charges in the magnetization of a magnet.

His observations had prompted him to compare the spreading from a single spark discharge of what he described as induction, with the spreading of light from a spark made with flint and steel. Here he was comparing what in fact were electro-magnetic waves with waves of light. His understanding had prompted him to suspect a similarity between these electrical effects and light, which was subsequently proved by Maxwell and Hertz. It is now common knowledge that the difference between radio waves and light waves is due to difference in wave-length only.

Henry's deduction of the similarity of the spreading of the electrical disturbance with the spreading of light was based on his simple calculation of the enormous volume of space through which the disturbance was observable. The electric spark could, as it were, be seen by the magnetic detector, as a lighted match could be seen by the eye.

He did not use the word " energy," as, in its modern sense, it had not, in 1842, been introduced into physics. But he saw that the energy of the spreading mechanism of the electrical disturbance, and that of waves of light, were of the same order, and he concluded that the electrical spreading must be due to an electrical plenum, or ether.

In 1842 Henry was unconsciously making experiments with radio waves, and had begun to formulate qualitatively some first rough ideas of an electrical ether which transmitted disturbances to great distances. He had started to approach the electro-magnetic theory of light.

He remarked again, in an address in 1851, that the inductive effects of the discharge current of a Leiden jar appeared to be "propagated wave-fashion," and that the inductive effects, which extend to such surprising distances, "must produce in surrounding space a series of plus and minus motions analogous to if not identical with undulations."

These speculations are to be compared with those of Faraday in his lecture of 1846, on "Ray Vibrations," which, according to Clerk Maxwell, contains the first proposal of the electro-magnetic theory of light. Faraday suggested that radiation was a species of transverse vibrations in lines of force. He believed this conception was implied by the phenomenon of the magnetic polarization of light, which he had discovered early in 1846 (with a powerful electro-magnet of the type invented by Henry).

Henry's greatest achievements were in electrical research, but he made many other interesting researches. He worked assiduously at meteorology, and his proposals for systematic world-weather observations, which were studied by the British Association in 1838, were wider than any before suggested. In 1831 he had shown that some aurorae are simultaneously visible in America and Europe, and are therefore due to general physical conditions of the globe, and not to local phenomena.

He used Melloni's thermopile in 1843 to measure the heat-radiation from the sky, and found that the vapours near the horizon were powerful reflectors of heat, but that the cloud of a distant thunder-storm was colder than the adjacent blue space.

He observed in 1839 that mercury could be siphoned through a height of three feet by a thick lead wire. Mr. Cornelius of Philadelphia, a manufacturer of bronzes, informed him that when silver-plated copper was heated to the melting-point, the silver was burned away. Henry dissolved the surface from such a piece of burned copper, with acid, and revealed the silver underneath. This proved that solid silver would dissolve in solid copper.

He extended the knowledge of the production of phosphorescence by rays, especially from sparks, and showed that phosphorescent rays excited by polarized light were completely depolarized. G. G. Stokes rediscovered this effect ten years later.

He described in 1843 an electrical chronograph for determining the velocity of projectiles. In one form the projectile was to be fired through wire screens, each of which was connected through an induction coil to a metal pointer nearly touching paper wound round a revolving metal drum. When a screen was broken, an induction current produced a spark between the pointer and the drum, which left a small hole in the paper. This method had the great merit of no inertia in the working parts. Wheatstone invented a method of measuring the velocity of projectiles some time after 1834, but did not publish it until 1845.

He investigated the cohesion of liquids in 1844. He measured the tenacity of a soap-film by " weighing the quantity of water which adhered to a bubble just before it burst." The thickness of the film was determined by an observation of Newton's rings. He concluded that the molecular attraction of water for water is several hundred pounds per square inch, and equal to that of ice for ice. The strength of the soap-film is due not to an increase in molecular attraction, but to the reduction of the mobility of the molecules. Further experiments showed that the cohesion of pure water is greater than that of soapy water. He explained that the change from the solid to the liquid state was due, not to the destruction of cohesion, but to the neutralization of the polarity of molecules, which gave them " perfect freedom of motion around every imaginable axis."

He gave an address in 1844 " On the Origin and Classification of the Natural Motors." His thoughts had been turned to this subject by some remarks by Babbage on " the economy of machinery," and by the researches of Liebig, Dumas, and Boussingault on vital chemistry. Henry writes that he believed he had brought the views of all these investigators together, in a manner that had not been done before. He concludes that the force of the burning fuel in an engine, and that developed by the moving animal, are ultimately derived from the sun's rays. He believed that the vital principle is restricted to the propagation of form and arrangement of atoms in living organisms. His views approximated to the theory of the conservation of energy.

He investigated in 1845 the relative heat-radiating power of portions of the sun's surface. A large image of the sun's disc was explored by a small thermopile. Henry found that the heat radiation from a large sun-spot was distinctly less than that from " the surrounding parts of the luminous disk." This research virtually founded a new branch of solar physics. It was extended by P. A. Secchi, who was a young professor in America at the time, and was assisted and encouraged by Henry.

After 1846, Henry's opportunities for research were again restricted by his working conditions. The account so far given describes the researches done before the age of forty-nine years. They form a great achievement, and the degree of Henry's ability is illustrated when it is considered that he was unable to start research until he was thirty years old, and had to work under very hard conditions until he was thirty-five. After he had done all this he became the first Secretary of the Smithsonian Institution, and directed its activities for thirty-two years.

III

THE SMITHSONIAN INSTITUTION

1

THIS Institution was founded with a sum of about £106,000, or $500,000, which passed into the hands of the Government of the United States in 1837, through the will of an Englishman named James Smithson, who died in 1829.

James Smithson was an illegitimate son of Sir Hugh Smithson, who became the first Duke of Northumberland.

Sir Hugh Smithson was the son of a Yorkshire baronet, or minor hereditary nobleman, who owned a small family estate. Country gentlemen of this sort usually managed their estates, and Hugh Smithson had been educated in this tradition. He was extremely handsome, energetic, capable, and ambitious. These qualities enabled him to marry, in 1740, Elizabeth Percy, the heiress of the wealth and connections of the Percy family. This family had large estates in Northumberland, which contained deposits of coal. The growth of industry in the latter half of the eighteenth century had prompted the improvement of the steam-engine, and following this achievement the demand for coal swiftly increased. Numerous coal mines were sunk on Smithson's estates, and the number of miners and the general population increased rapidly. The rent from the Northumberland estates increased from £8,607 in 1749 to about £50,000 per annum in 1778. This development was primarily due to the growth of the coal trade. The working conditions of the miners at this period were shocking. Women were used to draw tubs of coal along the pit galleries. The chains by which they hauled the tubs were fastened round their necks, and passed between their legs, where they made horrible sores through friction.

Smithson spent a large part of his income on ostentation. His wife's equipages often excelled those of the Queen, and his expenditure exceeded that of any other private person. The old nobility hated his pride and wealth, and regarded him as an upstart. George III was friendly with him, and in 1766 made him a duke, as a consolation for failure to receive the highest political offices.

Smithson was one of the new class of magnates which achieved wealth by the exploitation of the opportunities created by the introduction of steam power and machinery into industry. He had the virtues besides the vices of his class. He was business-like. He drained and reclaimed his land, repaired the houses, and planted twelve hundred trees a year for twenty years. Dutens wrote that "he had great talents and more knowledge than is generally found amongst the nobility." On the other hand, Walpole wrote that "with the mechanic application to every branch of knowledge, he possessed none beyond the surface." This was the opinion of a philosopher of the pre-industrial leisure class, and shows the usual prejudice of that class, as exemplified by Plato twenty centuries ago, against mechanical knowledge.

His attention to details was interpreted as "littleness of temper," he was despised for his "sordid and illiberal conduct" in gambling, and "although his expenditure was unexampled in his time, he was not generous, but passed for being so owing to his judicious manner of bestowing favours."

The same sense, which was that of a new sort of commerical magnate, led him to oppose the repression of the American colonies. His son Algernon, who became the second duke, fought against the Americans at Lexington. He also did not approve of the repression, and soon noted that the American insurgents were far more formidable than a mob, brave and not without military skill.

The first Duke of Northumberland was a leader of a new social class, and had fierce struggles for equality with the old nobility.

It is not surprising that a man of such good looks and wealth, accustomed to get what he wanted, should have had illegitimate children. A widow named Mrs. Macie bore him a son in 1765, who came to be known as James Smithson. This son was at first named James Lewis Macie, and adopted the surname Smithson about 1802.

Mrs. Macie was a member of the Hungerford family in Warwickshire, and a descendant of Henry VII through Lady Jane Grey. Thus James Smithson belonged to the new industrial nobility as a son of its most prominent member, and also to the old nobility, as of royal descent on his mother's side. Through his relationships he might have acquired the most magnificent social position, if he had not been illegitimate.

His father apparently prevented him from being plainly recognized as his son, and indirectly incorporated into the new nobility. If he had desired, he could probably have secured a title for him. But the Duke opposed direct recognition of his paternity. When Macie was entered as a student at Oxford in 1782, his father's name was suppressed in the registry of names. This was a very exceptional departure from university procedure, and could have been secured through great influence only.

Macie was a remarkable student. When he left Oxford in 1786, he was reputed to know more than any other person in the university about the chemistry of minerals. His scientific and social standing were sufficient to secure his election to the Royal Society in the following year, when he was twenty-two years old. One of his five recommenders for election was the eminent Henry Cavendish, of whom he became an intimate friend. As Cavendish was very shy and extremely able, Smithson could not have gained his rare confidence without tact and intelligence.

Smithson always had money. It seems to have come from his mother's family. The fortune which he bequeathed to the United States for founding the Smithsonian Institution came from the Hungerford family. Virtually nothing came from the vast wealth of his father and the Northumberland family.

Smithson was a clever analytical chemist. In his time, mineralogists confused native zinc carbonate and zinc silicate, and labelled them both calamine. He demonstrated their difference, and the first is now known as smithsonite, after his discovery. He devised methods of detecting small quantities of arsenic and mercury, which remained standard for half a century. He recognized substances combined together in definite proportions. His conception of chemistry was philosophical, and he wrote in a terse mode of expression more modern than the usual style of his day. He remarked in an early paper that " chemistry is yet so new a science . . . " that chemical knowledge consists " entirely of isolated points, thinly scattered, the lurid specks on a vast field of darkness."

He was advanced in his respect for accuracy and complete descriptions of experimental procedure. He had the modern equalitarian attitude towards scientific facts, and did not underrate, like most of his contemporaries, the value of accurate facts not obviously related to some fashionable theory. His remark that " every man is a valuable member of society, who, by his observations, researches, and experiments, procures knowledge for men," is in this spirit.

Like Humphry Davy, and other chemists of the time, he was interested in the application of science to technology. Smithson wrote that " in all cases means of economy tend to augment and diffuse comfort and happiness. They bring within the reach of the many what wasteful proceeding confines to the few." He then describes an improved method of making coffee. He analysed the colouring matters in plants and medicinal herbs, and he experimented with the construction of lamps.

Davy's social significance as a chemist has been interpreted as the propagandist of the application of chemistry to industrial manufacture. He helped to sell science to the rising capitalist industry of the nineteenth century. Smithson was in sympathy with this tendency. He urged the application of science, especially where it was of economic value. Benjamin Thompson (Count Rumford) had similar views. This American chemist founded the Royal Institution in London to encourage the application of science to the improvement of domestic and industrial economy. The English chemist Smithson founded an institution in America with rather similar objects.

When Smithson found himself with considerable wealth (virtually none of which came from his enormously rich father), he did not stop his scientific researches. He pursued them with much persistence. This seems to have been due to true scientific curiosity and also to a hope of intellectual fame which would surpass the social fame of the parent who had disowned him. His choice of mineralogy as an avenue to fame may be significant. Perhaps he wished to show how much more he knew about minerals than the father who had made so much money out of them. The motive might have been quite unconscious.

During the passage of years he became aware that his scientific talent was not great enough to accomplish spiritual revenge in this manner. Also, his health became feeble. He retired to Paris, where he divided his time between research and gambling. He became a close friend of Arago, who regretted " that this learned experimentalist should devote the half of so valuable a life to a course so little in harmony with an intellect whose wonderful powers called forth the admiration of the world around him." Arago tried to wean him from gambling by working out his prospective losses and gains by the laws of probability. Smithson was sufficiently impressed to restrict his stakes within his income, but he would not break the habit, because it was the only occupation which could distract him for a time from consciousness of his ailments.

Smithson had been born in France. Like many other liberal Englishmen he was sympathetic to the earlier changes of the French Revolution. He wrote from Paris in 1792: " *Ça ira* is growing the song of England, of Europe, as well as of France. Men of every rank are joining in the chorus. Stupidity and guilt have had a long reign, and it begins, indeed, to be time for justice and common-sense to have their turn . . . the office of king is not yet abolished, but they daily feel the inutility, or rather great inconvenience, of continuing it, and its duration will probably not be long. May other nations, at the time of their reforms, be wise enough to cast off, at first, the contemptible incumbrance."

When Smithson wrote his will, thirty-four years later, he was, no doubt, much less Jacobinical, but he retained a core of radicalism.

As his hope of great intellectual fame faded and his health declined, his resentment against his father, and his father's family and social class, increased. He felt that he was of a higher social class than his father, in virtue of royal descent through his mother, and yet his father disowned him, and refused even to have him established in his own upstart nobility. Smithson hated his father, and suffered from the psychological affliction described by Freud as the Oedipus complex. This complex was strengthened by the mark of old nobility and wealth he received from his mother and her family.

In his fury against those who thrust him out of the class to which he felt himself to belong, he wrote:

" The best blood of England flows in my veins; on my father's side I am a Northumberland, on my mother's I am related to kings, but this avails me not. My name shall live in the memory of man when the titles of the Northumberlands and the Percys are extinct and forgotten."

The desire to kill his father in revenge for social ostracism had been sublimated into the desire that his own fame should still live after that of his father and the Northumberlands was dead.

He conceived a method of achieving this through the bequest of his wealth. The first paragraph of his will reads:

" I James Smithson Son to Hugh, first Duke of Northumberland, and Elizabeth, Heiress of the Hungerfords of

Studley, and Niece to Charles the proud Duke of Somerset . . ."

A mineralogical chemist could not have composed this without being deeply impelled by class feeling.

He bequeathed a small legacy to an old servant, and the rest of his proprety to a nephew. If the nephew had no heir, the property was to go " to the United States of America, to found at Washington, under the name of the Smithsonian Institution, an Establishment for the increase and diffusion of knowledge among men."

It is not known how Smithson conceived this particular idea. There is no evidence that he had any contact with the United States or with American citizens. Only two books about the United States were found among his large collection of books and papers. One of these contained an enthusiastic forecast of the future of the city of Washington. This may have suggested that city as a suitable place for the establishment whose fame was to outlast that of the Northumberlands.

There is a passage in George Washington's farewell address which he may have read. " Promote, then, as an object of primary importance, institutions for the general diffusion of knowledge. In proportion as the structure of a government gives force to public opinion, it is essential that public opinion should be enlightened."

It is impossible to say whether Washington influenced Smithson. The probability is that both of them were influenced by the general social movement of the time for the diffusion of knowledge. Numerous societies and institutions were founded for this object at the beginning of the nineteenth century.

As a trained research worker Smithson carefully included " increase " of knowledge, and placed it before " diffusion," in the statement of his desire. He was more explicit on this point than Washington, the soldier and administrator.

Smithson's nephew died childless in 1835. The Government of the United States was informed of its right to his property and President Andrew Jackson communicated the information to Congress. The formalities of acquiring the property were completed in two years, which for the time was extremely swift, owing to the good-will of the British Government, and the energy of R. Rush, the American lawyer sent to London to prosecute the claim. Rush arrived with the bequest at New York in 1838. It was in the form of 105 bags, each of which contained 1,000 gold sovereigns, and another bag which contained 960 sovereigns, and " eight shillings and sevenpence wrapped in paper."

Congress debated desultorily for eight years as to how Smithson's will should be done. J. Q. Adams made the problem one of his special interests. He saw that if Smithson's scheme were successfully achieved, it would have a profound influence on the culture of the United States. He was anxious " to secure, as from a rattlesnake's fang, the fund and its income, forever, from being wasted and dilapidated in bounties to feed the hunger or fatten the leaden idleness of mountebank projectors and shallow and worthless pretenders to science."

Many different types of " establishment " were proposed. Some wished to found a university, others some sort of school, or museum, or astronomical observatory. The exclusion of a school from the proposals was secured only a few minutes before the end of the final debate. In the end, the fund was definitely secured for the foundation of an institute of higher learning.

The debates on the proposals reflect the attitudes of many of the leading men and classes of the United States of the 1830's towards science. John C. Calhoun opposed the acceptance of the bequest, on the ground that it was beneath the dignity of the United States to accept money from a private foreigner. He was also influenced by his principle of opposing any action which might strengthen the influence of Washington and the central authorities on the life of the United States. J. Q. Adams opposed the foundation of a school, on the ground that the education of citizens was the duty of the United States themselves, and should not be done at the expense of a foreigner's bequest. He pointed out that Smithson wrote that the institution was for the increase and diffusion of knowledge among men, and not among men of the United States only. It was to benefit all men.

John Davis firmly supported the acceptance of the bequest on the ground that " the establishment of institutions for the diffusion of knowledge " is " a vital principle of a republican government."

Joel R. Poinsett endowed the final scheme with the ideas of an important building, a national museum of art and science, its location in Washington, the main features of the adopted plan of organization, and the international exchange of books.

Robert Dale Owen (a son of Robert Owen) harmonized the proposals and prepared the first act of incorporation. He was assisted by A. D. Bache, who sought advice from Henry, and other scientists and scholars.

Henry was in England in 1837, when the Smithson bequest was definitely received by the United States. He had immediately become interested in its possibilities, and had retained his interest during the decade of debate. The board of the new institution hoped that Henry would become the first Secretary, or Director. He was persuaded to accept this position by Bache. He was asked to prepare a plan of organization, which he presented to the board in 1847.

He explains that Smithson's will indicates that the first object of the Institution must be the increase of knowledge, and the second, to diffuse it. " The Government of the United States is merely a trustee to carry out the design of the testator. The institution is private and not national. It is to serve the whole of mankind." Henry notes that Smithson has written that " the man of science has no country ; the world is his country—all men his countrymen." The Institution should therefore be conducted in that spirit, and should not in its programme give excessive weight to local interests.

Increase of knowledge was the first object. Henry proposed " to stimulate men of talent to make original researches by offering suitable rewards for memoirs containing new truths ; and, to appropriate annually a portion of the income for particular researches, under the direction of suitable persons." To diffuse knowledge, he proposed " to publish a series of periodical reports on the progress of the different branches of knowledge ; and, to publish occasionally separate treatises on subjects of general interest." The Institution should make special collections of objects and " also a collection of instruments of research in all branches of experimental science."

Henry held that specialization by the Institution on a particular branch of science was contrary to Smithson's intention. Any preference should be given to the higher and more abstract parts of science. " Incomparably more is to be expected " as to the future advancement of agriculture " from the perfection of the microscope than from improvements in the ordinary instruments of husbandry." He notes that in the United States " though many excel in the application of science to the practical arts of life, few devote themselves to the continued labor and patient thought necessary to the discovery and development of new truths." This is due, he considers, to the want, " not of proper means, but of proper encouragement." He considers that the publication of original work " will act as a powerful stimulus to the latent talent of our country, by placing in bold relief the real laborers in the field of original research."

He was much impressed by the cost of publication of scientific papers, especially those on natural history, which contained many illustrations. The difficulty of publication had a large influence on the development of the Smithsonian system of distributing literature. He thought that the award of " fifty or a hundred dollars " would often provide an investigator with the necessary books, equipment, or manual assistance.

He considered that the " principal means of diffusing knowledge must be the *Press*." By this he meant all forms of printed publication. In his usage, *Press* did not refer only to daily newspapers. He proposed the publication of periodical reports of the progress of science, written in simple language.

Henry was personally opposed to the formation of a museum. He considered that this ought not to be undertaken at the expense of the Smithsonian bequest. But for the present, as it was incorporated in the approved scheme, he proposed that they should, firstly, collect objects which facilitated the " study of the memoirs which may be published " ; secondly, objects not generally known in the United States ; and thirdly, " instruments of physical research which will be required both in the illustration of new physical truths and in the scientific investigations undertaken by the Institution." He suggests as subjects of physical research, terrestrial magnetism, which has great theoretical interest, and also " direct reference to navigation, and to the various geodetical operations of civil and military life." The organization of a telegraphic meteorological service for the whole country, and in co-operation with the British Government, was desirable. This might lead to the solution of the problem of American storms. Exploration, which would provide material for a Physical Atlas of the United States, should be subsidized.

Physical constants, such as the weight of the earth, the velocity of light and electricity, should be re-determined. Soils and plants should be analysed. Statistical inquiries concerning physical, moral and political subjects should be made, and archaeology and ethnology supported.

Henry began to direct the Institution in 1846. He continued to be the director for thirty-two years. Before commenting on the nature of his policy, it will be helpful to consider in what degree it was achieved.

2

When Henry died in 1878, the Institution had a capital investment of $686,000. The value of the building and furniture was estimated at $500,000, the library at $200,000, philosophical apparatus at $5,000, the stock of its own unsold publications at $50,000, and other items, making $782,000. The total value was $1,468,000.

Thus in thirty-two years, by careful management, Henry had doubled the value of Smithson's bequest. He had paid for all building and development out of the interest on the original capital, which had not been diminished, but increased.

Henry pursued this rigidly economical policy during an exceptionally unsettled period of American economic and political history. During the first half of his secretaryship, when the Southern statesmen had the dominant power, investments and banking were under insufficient supervision and were insecure. The second half of his secretaryship began during the Civil War. He held the Institution together during that uncertain period, when it might have dissolved during the social turmoil. He conceived saving in expenditure as the basis of sound financial management. When he was appointed to the secretaryship his salary was $3,500, or about £700 per annum, with free living-rooms in the building. He was urged on several occasions during his thirty-two years of service to accept an increase in salary, but he always refused. In 1846 the salary was perhaps not trivial, but in the America of 1878 it was inadequate. Henry was the chief scientific personage in the American capital. He had to entertain numerous visitors. He insisted on doing all this on the same salary in 1878 as he had received in 1846. His daughter has written that this was accomplished only by the most stringent economy in his home.

Henry prepared the Report of the Institution himself. He wrote simple summaries of recent advances in science, reprinted lectures delivered in the Institution, and interesting articles from inaccessible foreign journals.

In 1872 the edition of the Report contained 20,000 copies. It declined afterwards to ten or fifteen thousand.

The *Smithsonian Contributions to Knowledge* consisted of volumes of original papers. Henry wrote that " the real working-men in the line of original research hail this part of the plan as a new era in the history of American science." They were published in editions of 1,000, and distributed freely among libraries, about 350 of which were in foreign countries. The volumes of *Miscellaneous Collections* dealt with reviews of the present state of knowledge in different branches of science, and with accounts of extensive collections of materials for research, reports of explorations, history of science, etc. These also were issued in editions of 1,000 copies and distributed freely.

Besides these issues, the Institution published many volumes on special subjects, and various scientific bulletins.

Under Henry's direction, the Institution developed a system of international exchange of scientific knowledge.

A remarkable Frenchman named A. Vattemare, who was educated as a surgeon, and became a famous ventriloquist, retired from the stage in order to urge the exchange of duplicate books between the libraries of the world. He visited the United States in 1839 and aroused much interest in his scheme. The Smithsonian Institution adopted the idea, and also agreed to act as a clearing-house for the dispatch of scientific publications from any American institution to suitable addresses in other parts of the world. The Royal Society of London obtained an order from the British Government that these packages should be admitted free of duty, and the Government of the United States similarly exempted packages addressed to the Smithsonian Institution. Various steamship companies granted concessions on the freight rates for the packages. The exchange service was used by the United States Government for distributing its own reports, of which 20,000 packages were distributed between 1851 and 1867. It grew into an international service for the exchange of books, journals, and natural history specimens, assisted by the governments of many countries of the world. Isolated investigators far from libraries and colleagues could obtain books and specimens through the Smithsonian Institution. The list of addresses of correspondents had grown to 23,408 in 1895, of which 10,765 were those of libraries, and the remainder of private individuals. The aim of " diffusing knowledge " was grandly achieved.

In 1851 Henry reported on the necessity for the proper indexing of scientific knowledge. He explained that Young had compiled a valuable catalogue of scientific books, including works up to the year 1807. A new universal catalogue was now required. He started a bibliography of American scientific works and papers in 1854, and suggested to the British Association that a similar index of British and European works should be made. A committee of the British Association, consisting of Cayley, Grant, and Stokes, approved the suggestion. They persuaded the Royal Society to prepare a catalogue of scientific works and papers published since 1800. The first volume of this great catalogue was published in 1867.

The bibliography of science grows in importance with the progress of science. It is becoming as important, if not more important, than any particular branch of science, as it is the key to the results of scientific research. The quick and certain finding in the literature of what has already been discovered is now as important, in some branches of science, as new discovery. An increasing amount of effort in modern research is wasted through failure to appreciate what has been done.

Henry was one of the chief founders of the bibliography of modern science. He inspired the development of one of the most important instruments which aids research.

The organization of a museum was one of the items required by the original scheme. Henry was opposed to this proposal, as he foresaw that the cost of keeping the increasing collections would ultimately exceed the resources of the Institution. But he obeyed the requirement. The collection became the nucleus for the United States National Museum, which was housed in a separate building in 1881. In 1927 the National Museum possessed ten million objects.

The Bureau of American Ethnology grew out of John W. Powell's exploration of the Grand Canyon of the Colorado, which was begun in 1867, and fostered by Henry, as the Secretary of the Institution. Henry was much interested in researches concerning the aborigines of America and their pre-history.

His colleague and successor, Spencer F. Baird, was a zoologist, and used the resources of the Institution to foster the study of natural history. His own specimens were the nucleus of the National Museum's natural history collections. His studies of fish and fisheries led him to the conception of the conservation of the natural fisheries, and of " fish culture," as a method of producing food, analogous to stock-raising. He inspired the foundation of Woods Hole, and many other biological research laboratories, where the knowledge necessary for the development of " fish culture," and the general advance of zoology, could be acquired. The details of the international exchange of books and specimens were supervised by Baird.

The magnitude of the administrative work of Henry and his colleagues is shown by the number of letters written by Henry. A fire occurred in his office and adjoining parts of the Institution in 1865, and copies of 30,000 pages of letters drafted by him were destroyed. He personally wrote a large part of the thirty-two Annual Reports issued during his secretaryship.

As W. H. Taft remarked in 1927, the Smithsonian Institution has been " the incubator of American science." C. G. Abbot said that its policy had been to " seek facts irrespective of their apparent economic value," and that " cooperation and not monopoly is the motto which indicates the spirit of the Smithsonian's operations."

The original plans for the diffusion of knowledge were carried out by Henry with extraordinary fidelity and success.

The international exchange of books and specimens was an original contribution towards the internationalization of scientific knowledge and the unification of human culture.

The Smithsonian Institution gave birth to several of the national scientific institutions of the United States.

3

The first object of the Institution was to increase knowledge. Henry made and assisted many researches during the thirty-two years of secretaryship.

His project for obtaining simultaneous meteorological reports by telegraph from observers over a large area was established in 1849, with the assistance of five hundred observers. The information received was plotted daily, by means of adjustable symbols, on a large map of the United States. " It was often enabled to predict (sometimes a day or two in advance) the approach of any of the larger disturbances of the atmosphere."

Henry explained the importance of this knowledge to navigation and agriculture. By his application of the electric telegraph to meteorological reports, he became the founder of modern meteorological forecasting of the weather.

This branch of the Institution's work became the nucleus of the Government's meteorological bureau, which was established in 1870.

Henry made in 1873 an arrangement with the Atlantic Cable Companies, by which information of new astronomical observations was transmitted without charge between the Institution and the chief observatories of Europe. This has been of much importance in the study of variable stars, *novae*, sunspots, and other swiftly-changing astronomical phenomena. Henry helped to persuade Lick to found the famous observatory that bears his name.

He became a member of the United States Lighthouse Board in 1852.

The lighthouse lamps at that time used whale oil. As its cost was increasing, a cheaper substitute was desirable. Henry made accurate photometric measurements in a black room on the illuminating power of various oils. He found petroleum oil was unsafe owing to variation in quality. At low temperatures lard oil could be used successfully. It was immediately introduced into the lighthouse service, and as its cost was only one-fourth that of whale oil, it enabled a saving of about $100,000 per annum to be made.

He began a long series of experiments on the acoustics of the atmosphere, in connection with the improvement of fog-horns for the protection of shipping during seaboard fogs. He showed that gun signals were the most inefficient form of sound warning. Steam whistles were inferior to trumpets, and both were inferior to sirens. Horns were of no value beyond short distances. He used an "artificial ear," or phonometer, consisting of a Sondhauss stretched membrane sprinkled with sand, for measuring the intensity of sounds. He recommended machines operated by steam at 60–80 lb., emitting a note of 400 vibrations per second. Under favourable conditions they could be heard at a distance of twenty miles. As a result of these researches the American fog-signal service in 1873 was far superior to that in Europe.

He discovered by observation in 1867 that a sound arriving against the wind could be heard more easily at the mast-head than on the deck. He learned that G. G. Stokes had forecast this effect in 1857, from the theory of wave-motions in fluids whose various layers moved at different velocities.

He determined the velocity of the wind at high altitudes by measuring the speed of the movement of the shadow of a cloud along the ground. This research should interest modern investigators who study the velocity of the wind at high altitudes, in order to assist airmen.

His fog-horn studies were pursued actively during the last decade of his life. He spent many weeks at sea in rough weather patiently collecting observations. His last report on them was published in 1877, when he was eighty years old. In the summary of his results he stated that the audibility of a sound at a distance depends on pitch, loudness, and quantity. It is affected by the state of the atmosphere. Perfect stillness and uniform density and temperature are most favourable to distant transmission. The most efficient cause of difference in audibility is the wind. The effect is not due to the velocity of the wind, but to refraction downwards of sound beams which otherwise would pass over the observer. Sometimes sounds are heard best against the wind. This is due to a dominant upper wind, whose direction is contrary to that of the wind at the surface. The existence of these upper winds was proved by means of balloons, and observations of the movement of the north-east storms on the coast of Maine.

The concentration of sound by concave reflectors and horns is of no value beyond a distance of three or four miles, or even less.

Experiments showed that neither fog, snow, hail, nor rain materially interfered with the transmission of loud sounds. Sirens were heard at greater distances during fogs.

Some instances of sound shadows due to projecting land and buildings were observed.

The " belt of silence " phenomenon was thoroughly investigated. When a ship sails away from a siren, the sounds often suddenly become inaudible, and then become audible again, at a greater distance. These " belts of silence " were carefully investigated. The phenomenon was observed only when the sound was moving against the wind, and was due to the upward refraction of the sound, which carried it over the observer. The beam continued upward until it reached another layer of air current, after which it was bent down again, and so became audible at a greater distance. Henry also gave two other explanations which hold in some cases.

The designing of the Smithsonian building and its rooms involved his interest in the problems of architecture and acoustics. He was of the opinion that " the buildings of a country and an age should be ethnological expressions of the wants, habits, arts, and feelings of the time in which they were erected." He did not consider architecture a fine art, like painting or sculpture. The temples of Egypt, Greece and

Rome were intended (partly) to " transmit to posterity, without the art of printing, an impression of the character of the periods in which they were erected." The Greek architect designed temples " to gratify the tutelar deity," and " was untrammelled by any condition of utility." They were intended " for external worship, and not for internal use." But " modern buildings are made for other purposes than artistic effect, and in them the aesthetical must be subordinate to the useful ; though the two may co-exist, and an intellectual pleasure be derived from a sense of adaptation and fitness, combined with a perception of harmony of parts, and the beauty of detail."

He contended that servile copies of ancient styles are " as preposterous as to endeavour to harmonize the refinement and civilization of the present age with the superstition and barbarity of the times of the Pharaohs."

Architecture should be consonant with the character of the people, climate, and " the material to be employed in construction. The use of iron and of glass requires an entirely different style from that which sprang from the rocks of Egypt," Greek marble and Roman brick.

He suggests that " the great tenacity of iron, and its power of resistance to crushing " should allow the construction of buildings of " far more slender " design, and " apparently lighter arrangement of parts."

After expressing these opinions, which, in 1856, were remarkably advanced, he discussed lecture-room acoustics. He noticed that though much research had been made into the nature of sound, there had been little practical application of the results. He described the arrangements of seats which give the best audibility, and methods of avoiding echoes and reverberation, according to theory and experiment. He proved experimentally that india-rubber absorbs sound by converting part of its energy into heat. The rubber's rise in temperature, when bombarded by sound, was measured by an iron-copper thermopile buried in it.

He was consulted in 1851 on the properties of the marble used in the extension of the United States Capitol, and investigated methods of testing building materials.

Pieces of marble were cut and ground into cubes with one-and-a-half-inch edges. Henry discovered that if the cubes were pressed between sheets of lead in a powerful press, they collapsed under about 30,000 lb. pressure, whereas when in direct contact with the steel plates of the press, they resisted about 60,000 lb. pressure. It had been expected that the lead packing would increase the resistance to pressure by distributing the load equably. Henry explained the unexpected result. " The stone tends to give way by bulging out in the center of each of its four perpendicular faces, and to form two pyramidal figures with their apices opposed to each other at the center of the cube, and their bases against the steel plates. In the case where rigid equable pressure is employed, as in that of the thick steel plate, all parts must give way together. But in that of a *yielding* equable pressure, as in the case of interposed lead, the stone first gives way along the outer lines or those of least resistance, and the remaining pressure must be sustained by the central portion around the vertical axis of the cube."

In the second part of his paper, published in 1855, Henry applied his ideas on the cohesion of liquids, which have already been mentioned, to the breakdown of metals under stress. He attributes rigidity not to direct attractive power between atoms, but to lateral cohesion, or resistance to slipping. The tensile strength of liquids and solids is of the same order, and their difference in rigidity is due to difference in the resistance of their atoms to slipping. When the " crystalline arrangement is perfect, and no lateral motion is allowed in the atoms, the body may be denominated perfectly rigid." Cast steel is an approximate example, as it ruptures with a " transverse fracture of the same size as that of the original section of the bar."

" The effect however is quite sufficient when we attempt to pull apart a rod of lead. The atoms or molecules slip upon each other. The rod is increased in length and diminished in thickness until a separation is produced."

Henry deduced that as tenacity is due to lateral cohesion, or resistance to slip, " the form of the material ought to have some effect upon its tenacity, and also that the strength of the article should depend in some degree upon the process to which it has been subjected."

He showed that a lead rod became hollow under an appropriate tension. He attributed this to the constraint of the inner atoms by the outer atoms. The outer atoms had relatively more freedom. " The inner fibres (if I may so call the rows of atoms) give way first and entirely separate, while the exterior fibres show but little indications of a change of this kind."

He deduced " that metals should never be elongated by mere stretching, but in all cases by the process of wire-drawing, or rolling."

His theory of slip explained the production of a hollow inside an iron bar by hammering, and he concluded that many of the breakages of the axles of locomotive engines were due to shaping by hammering, instead of rolling.

Henry used the equipment of the United States Navy Yard in making these brilliant researches, and was assisted by J. A. Dahlgren, who afterwards invented the ironclad which had such an important rôle in helping to win the Civil War for the Northern forces. It would be interesting to know whether the adoption of Dahlgren's ship was due to Henry's influence.

During the Civil War Henry became the chief adviser to the Government on scientific military inventions. He wrote several hundred reports, requiring much experimental investigation, on numerous military inventions.

The testing of materials for munitions contracts was also referred to him.

As a scientist, Henry had an essential rôle in the military organization of the Northern Government. His later career illustrates the close connection between science and military technique. The scientist is now becoming the most important unit in warfare.

4

Henry described the substance of his religious beliefs some days before his death in 1878. He wrote to Joseph Patterson that " we live in a universe of change." The wisdom of one man, and even of all men accumulated through centuries, is very small compared with the unknown. Unfathomable mysteries environ man on every side. But he believed the conception of the existence of one Spiritual Being is the simplest which gives human experience any intelligibility. This Being created man with intellectual faculties sufficient to gain, through what is named Science, some understanding of the operations of Nature.

He believed that this Being in unchangeable. The operations of Nature will always be in accordance with the same laws, under the same conditions. " Events that happened a thousand years ago will happen again a thousand years to come, provided the condition of existence is the same." He considered the existence of natural law evidence for the existence of an intellectual director of the universe.

He based the existence of a Creator on the grounds that " It is one of the truths best established by experience in my own mind, that I have a thinking, willing *principle* within me, capable of intellectual activity and moral feeling. . . . It is equally clear to me that you have a similar spiritual principle within yourself, since when I ask you an intelligent question you give me an intellectual answer. . . . When I examine the operations of Nature, I find everywhere through them evidences of intellectual arrangements, of contrivances to definite ends, precisely as I find in the operations of man ; and hence I infer that these two classes of operations are results of similar intelligence . . . in my own mind, I find ideas of right and wrong, of good and evil. These ideas, then, exist in the universe, and, therefore, form a basis of our ideas of a moral universe. Furthermore, the conceptions of good which are found among our ideas associated with evil, can be attributed only to a Being of infinite perfections, like that which we denominate 'God.' "

This theology is essentially the same as that of his Scottish Puritan ancestors. It ascribes great importance to the deterministic aspects of the universe, and to the existence of law. Simultaneously, it ascribes equal importance to the " willing *principle* within."

A theology which ascribes equal importance to determinism and will is one of the least unfavourable to the progress of science. Persons who have acquired this system of thought believe that an order of nature exists, and have the confidence that it may be discovered by energetic applications of the will. The rise of modern science is intimately connected with the rise of Puritanism. Both Puritanism and modern science are connected with the rise of a new social system. It is sufficient for the present point to note that Henry was equipped in childhood with beliefs in the obedience of nature and man to law, and the importance of obedience to moral intuitions.

W. B. Taylor writes that Henry had a natural quickness of temper in his youth, and retained a high degree of sensibility. His first interests were fiction and the drama. His temperament was of the sanguine type, which, according to Pavlov, is the best. He could " forget what had been painful in his past experiences, and . . . remember only and enjoy that which had been pleasurable." He moulded the lively material of his temperament according to his theological principles, and schooled himself to obedience to his moral intuitions. Systematic exercise of will gave him remarkable self-control. In his later years casual acquaintances considered him reserved and unimpressible. They thought his sense of humour limited, partly because he would not respond to any sort of humour which involved cruel thoughts about others.

" He accepted all the appointments of nature and Providence as the expressions of Infinite Wisdom, and so in everything gave thanks."

In 1865, when he was sixty-eight years old, a great fire in the Institution destroyed the voluminous records of his correspondence on many matters and with many persons throughout the world, his lifetime's collection of unpublished notes of researches, and Smithson's own literary remains and mineralogical collection, and other irreplaceable things, and also the manuscript of his forthcoming Annual Report. He wrote to a friend, some days after this occurrence : " A few years ago such a calamity would have paralyzed me for future efforts, but in my present view of life I take it as the dispensation of a kind and wise Providence, and trust that it will work to my spiritual advantage."

Henry's sense of discipline is seen in his opinions on education. He writes that the " first remark which may be made in regard to education is that it is a forced condition of mind or body. As a general rule it is produced by coercion." It is obtained only through hard labour by the educator and the pupil. Prospects of reward, emulation, and appeals to affection may stimulate the pupil, but an ultimate resort by the educator to force must always be possible. " The child, if left to itself, would receive no proper development," and the " savage never educates himself mentally." If all educational institutions were abolished, " how rapidly would our boasted civilization relapse into barbarism." He did not believe that it was " the manifest destiny of humanity to improve by the operation of an inevitable, necessary law of progress." He considered that civilization " is a state of unstable equilibrium which, if not supported by the exertions of individuals, resembles an edifice with a circumscribed base, which becomes the more tottering as we expand its lateral dimensions, and increase its height."

It cannot be preserved without the labour of a large proportion of thoroughly educated persons, and cannot be advanced without making special provision for " the *actual increase* of knowledge, as well as for its diffusion." Rewards and honours should be given to " those who *really add* to the sum of human knowledge."

This truth was not generally appreciated, and the tendency was to " look merely at the immediate results of the application of science," and " to liberally reward and honor those who simply apply known facts rather than those who *discover* new principles."

A high state of civilization could be preserved only by the exertions of individuals actuated by " a generous, liberal, and enlightened philanthropy." Unfortunately, the increase of wealth and security tended to relax individual effort. " Man is naturally an indolent being, and unless actuated by strong inducements or educated by coercion to habits of industry, his tendency is to supineness and inaction." The growth of wealth and elementary education " without a corresponding increase of higher instruction " rendered the " voice of the profound teacher " less and less audible, and " obliged him to comply with popular prejudices." These conditions fostered charlatanism.

The growth of specialization, or subdivision of labour in research, narrowed the number of persons thoroughly conversant with any field of knowledge. These small groups of well-informed persons " are not generally the dispensers of favor," and " he who aspires to wealth or influence seeks not their approbation." Those actively engaged in the business of life have little time for profound thought. They must receive knowledge at second hand, and yet " they are not content under our present system of education with the position of students." They wish to be teachers, and become ambitious of authorship, and " impatient for popular applause." Knowledge becomes increasingly superficial in proportion to its diffusion. " In such a condition of things it is possible that the directing power of an age may become less and less intelligent as it becomes more authoritative, and that the world may be actually declining in what constitutes real moral and intellectual greatness, while to the superficial observer it appears to be in a state of rapid advance."

Writing in 1854, he does not assert that this is the case in his own time, but he is " merely pointing out tendencies."

He complained that though his was emphatically a reading age, it was not " proportionately a *thinking* age." The world suffered from too many bad books, and ill-digested reading.

He attacked the contemporary state of copyright, which injured reputable authors by depriving them of payment. It damaged American education, because unsuitable textbooks pirated from abroad were cheaper than suitable books written by Americans who understood their own conditions. He considered that the writing of elementary textbooks was specially difficult, and should not be left to superficially qualified authors. He disagreed with the view that " superficial men are best calculated to prepare popular works on any branch of knowledge."

He based his suggestion for methods of educating the young on the observation that " memory, imitation, imagination and the faculty of forming habits exist in early life, while the judgment and the reasoning powers are of slower growth." Children should learn languages and moral precepts. The acquisition of facility in mental operations such as speaking, writing, reading and calculation, is " the most important part of elementary mental instruction," but it is tedious to the teacher and pupil.

It is " preposterous . . . that the child should be taught nothing but what it can fully comprehend." This inverted the natural order of the evolution of the faculties of understanding, and produced " remarkably intelligent children who will become remarkably feeble men."

He laid " great stress upon the early education of the habits." Persons trained in good habits will act well in crises where they have no time to think, and also in old age, when the will is no longer strong enough to control bad habits early acquired.

Henry's views on the nature of man, and the best methods of education, also exhibit the influence of Calvinistic ideas. He believed that " the laws which govern the growth and operations of the human mind are as definite and as general in their application as those which apply to the material universe," but, " unfortunately," psychologists have made little progress towards their discovery.

Henry's tough-mindedness, and dislike of obscurantism, is seen in his contempt for spiritualism. Newcomb relates that a noted spiritualist succeeded in capturing Lincoln's interest during his presidency. Lincoln urgently requested Henry to receive him, and investigate his apparent power of drawing noise from various parts of a room. Henry observed the proceedings, and said that though he could not say how the sounds were produced, they certainly came from the spiritualist's person. Some time afterwards, Henry met a young man in a railway train, who presently told him that he was a maker of telegraph instruments, and even supplied mediums with apparatus for producing their manifestations. Henry asked which mediums he had supplied, and learned that

Lincoln's acquaintance was among them. The young man explained that the manifestations were produced by apparatus fastened to the muscular part of the upper arm, which could be operated merely by contracting the muscles, without moving the joints, so that no movement was visible.

The firmness of Henry's mind is seen in his views on evolution and natural selection. The controversies on these ideas arose in the last years of his life, but, unlike the majority of earnestly religious persons, he was not antagonistic to them. He disagreed with his friend Agassiz, who denied them, and remarked that the theory of natural selection seemed to be the first genuine scientific theory that had been discovered in natural history.

Henry's genius was broad and collective. He could do innumerable things, and all of them well.

BIBLIOGRAPHY

Smithsonian Miscellaneous Collections. Volume 21. 1881. Volume 30. 1887.

Smithsonian Contributions to Knowledge. Volume 18. 1873.

The Smithsonian Institution 1846–1896. G. B. Goode, & cont. 1897.

" Sir Hugh Smithson : 1st Duke of Northumberland." *The Dictionary of National Biography.*

Conference on the Future of the Smithsonian Institution. W. H. Taft and C. G. Abbot. 1927.

Edith W. Stone : " Joseph Henry." *Scientific Monthly.* Sept., 1931.

Library for the Diffusion of Useful Knowledge : *Natural Philosophy.* 4 volumes. 1829–1838.

Mary A. Henry : " Joseph Henry." *Electrical Engineer.* New York. Jan. 13–March 9, 1892.

The Fool of Quality. Henry Brooke. With a preface by Charles Kingsley. 1859.

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